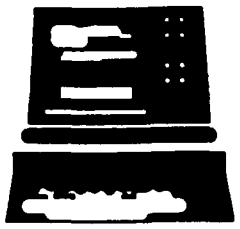

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U.S. ARMY INSTITUTE FOR RESEARCH
IN MANAGEMENT INFORMATION,
COMMUNICATIONS, AND COMPUTER SCIENCES

APPLIED ARTIFICIAL INTELLIGENCE SEMINAR (ASQBG-A-89-035)

JULY 1989

AIRMICS
115 O'Keefe Bldg
Georgia Institute of Technology
Atlanta, GA 30332-0800

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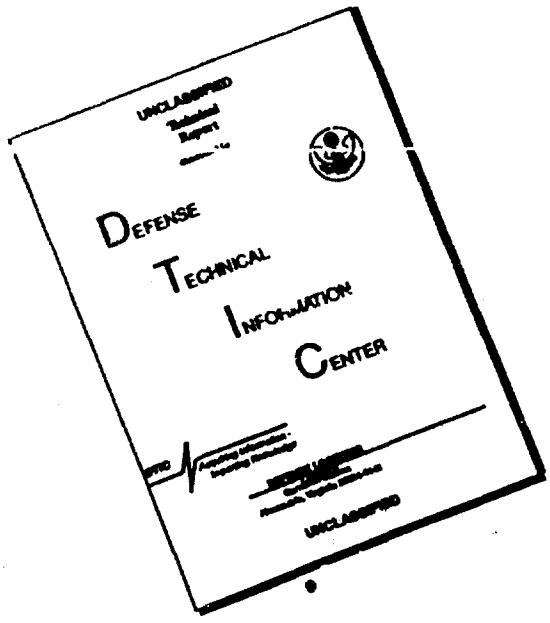

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THIS REPORT HAS BEEN REVIEWED AND IS APPROVED

s/ James Gantt
James Gantt, Chief
Management Information
Systems Division

s/
John R. Mitchell
Director
AIRMICS

APPLIED ARTIFICIAL INTELLIGENCE SEMINAR

In Partial Fulfillment of
Contract DAKF11-88-D-0011
Task 2

Presented by Coopers & Lybrand Decision Support Group

C&L COOPERS & LYBRAND
DECISION SUPPORT GROUP

INTRODUCTION

AGENDA

DAY 1

Introduction

History of Artificial Intelligence

Understanding Knowledge Intensive Activities

Understanding Knowledge

Understanding Reasoning

Overview of Methodology

DAY 2

Application Area Selection

Knowledge Elicitation

- *overviews*
- *techniques*

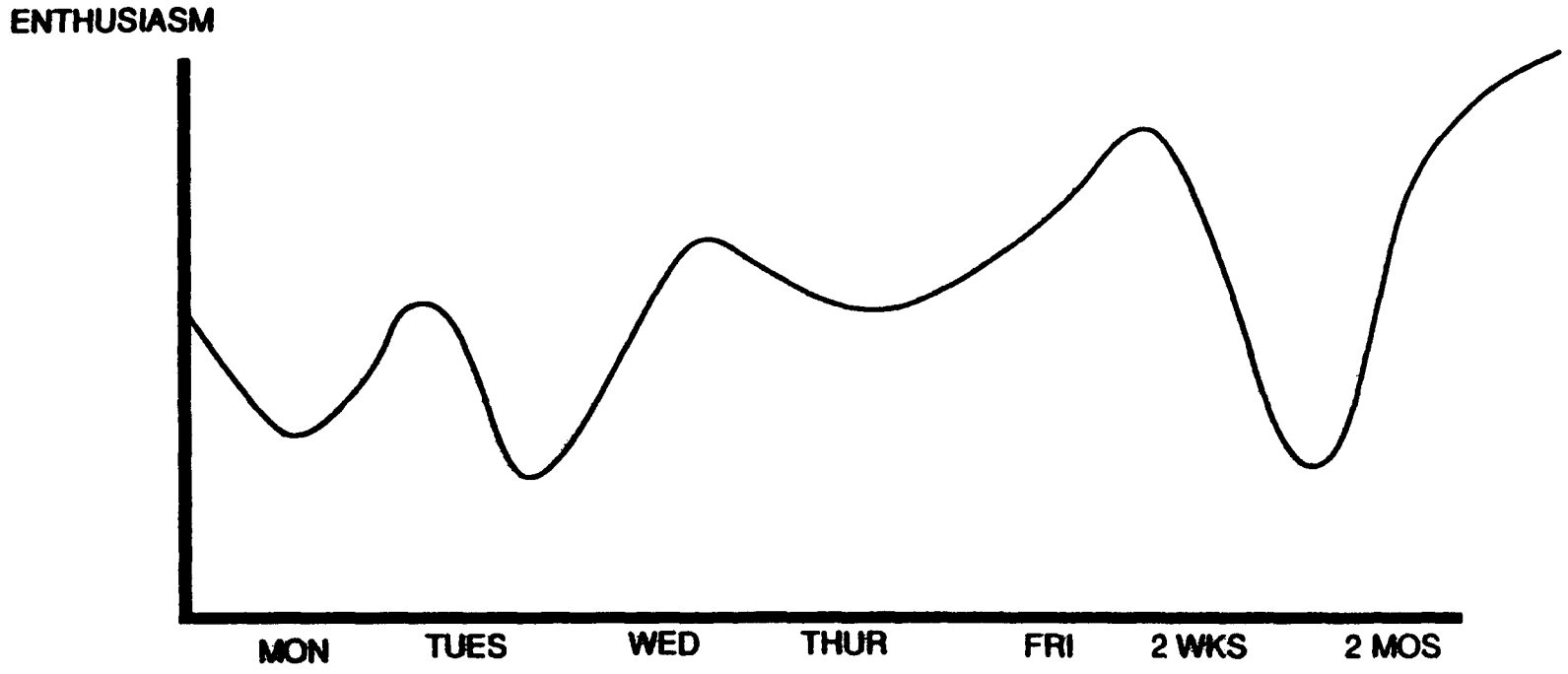
Project Management & Roles of the Project Team

System Design

Selecting Tools

Open Discussion

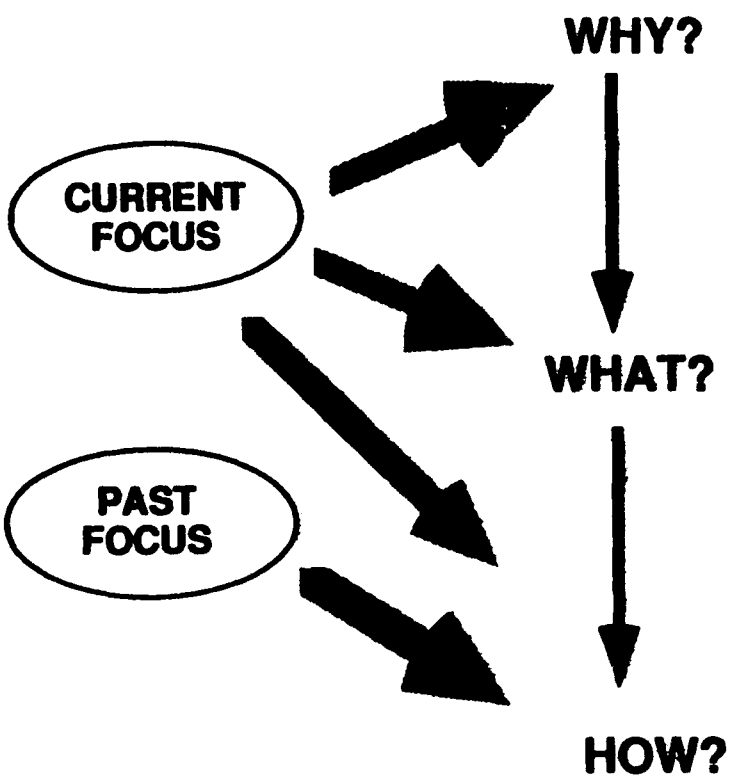
COURSE DYNAMICS



WHAT IS ARTIFICIAL INTELLIGENCE?

- A COLLECTION OF SOPHISTICATED COMPUTER TOOLS AND TECHNIQUES
- A METHODOLOGY FOR APPLYING THESE TOOLS AND TECHNIQUES
- AN APPROACH TO EMULATING HUMAN PROBLEM SOLVING TASKS
- A NEW PERSPECTIVE ON WHAT CAN BE AUTOMATED
- A STRATEGY FOR MANAGING KNOWLEDGE AS A CORPORATE RESOURCE

FOCUS OF AI EFFORTS



WHY?

BUSINESS OBJECTIVES

CRITICAL KNOWLEDGE FACTORS

WHAT?

SYSTEM ROLE

KNOWLEDGE MODEL

HOW?

HARDWARE REQUIREMENTS

SHELL SELECTION

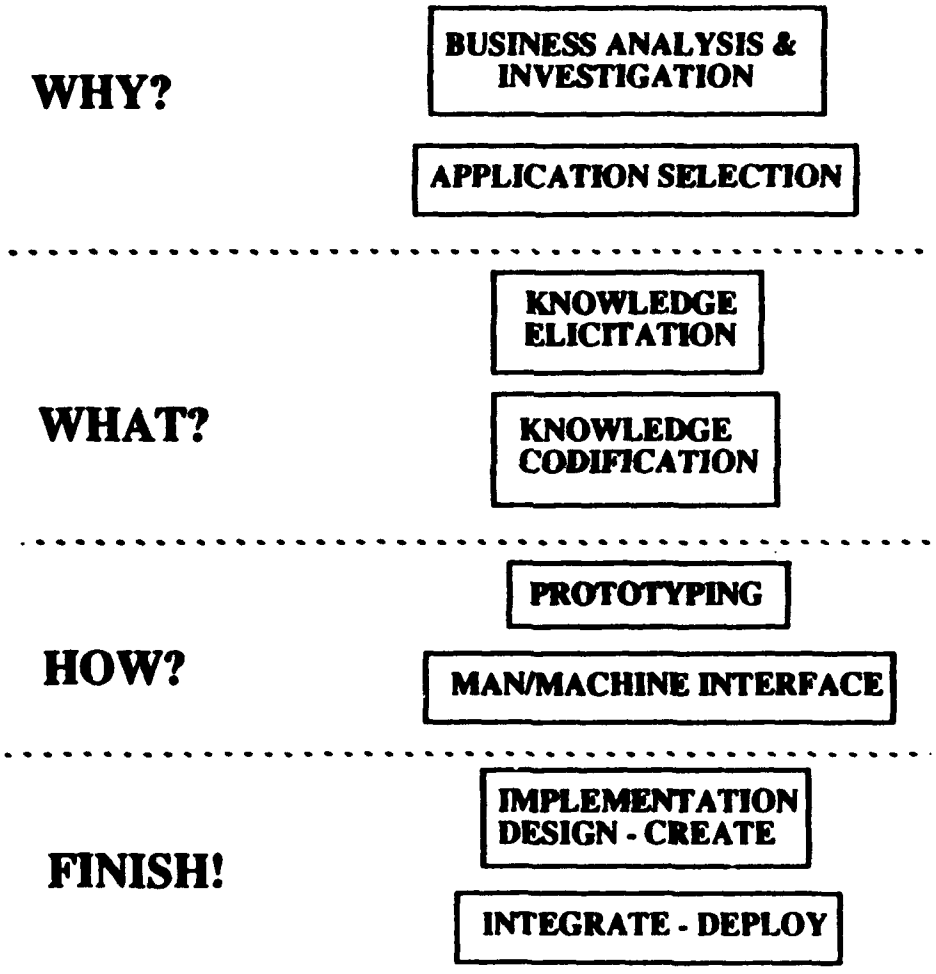
ENCODING

LISP PROGRAMMING

SKILLS NECESSARY TO DO AI

- **Understanding Operating and Business Environments**
- **Understanding Knowledge Tasks**
- **Cognitive Science**
- **Knowledge Elicitation**
- **Knowledge Analysis**
- **Rational Reconstruction**
  - Knowledge Encoding
  - AI Architectures
  - AI Programming
- **Man-Machine Interfaces**
- **Conventional CS Technologies**
- **MIS Integration**

KBS IMPLEMENTATION PROCESS OVERVIEW



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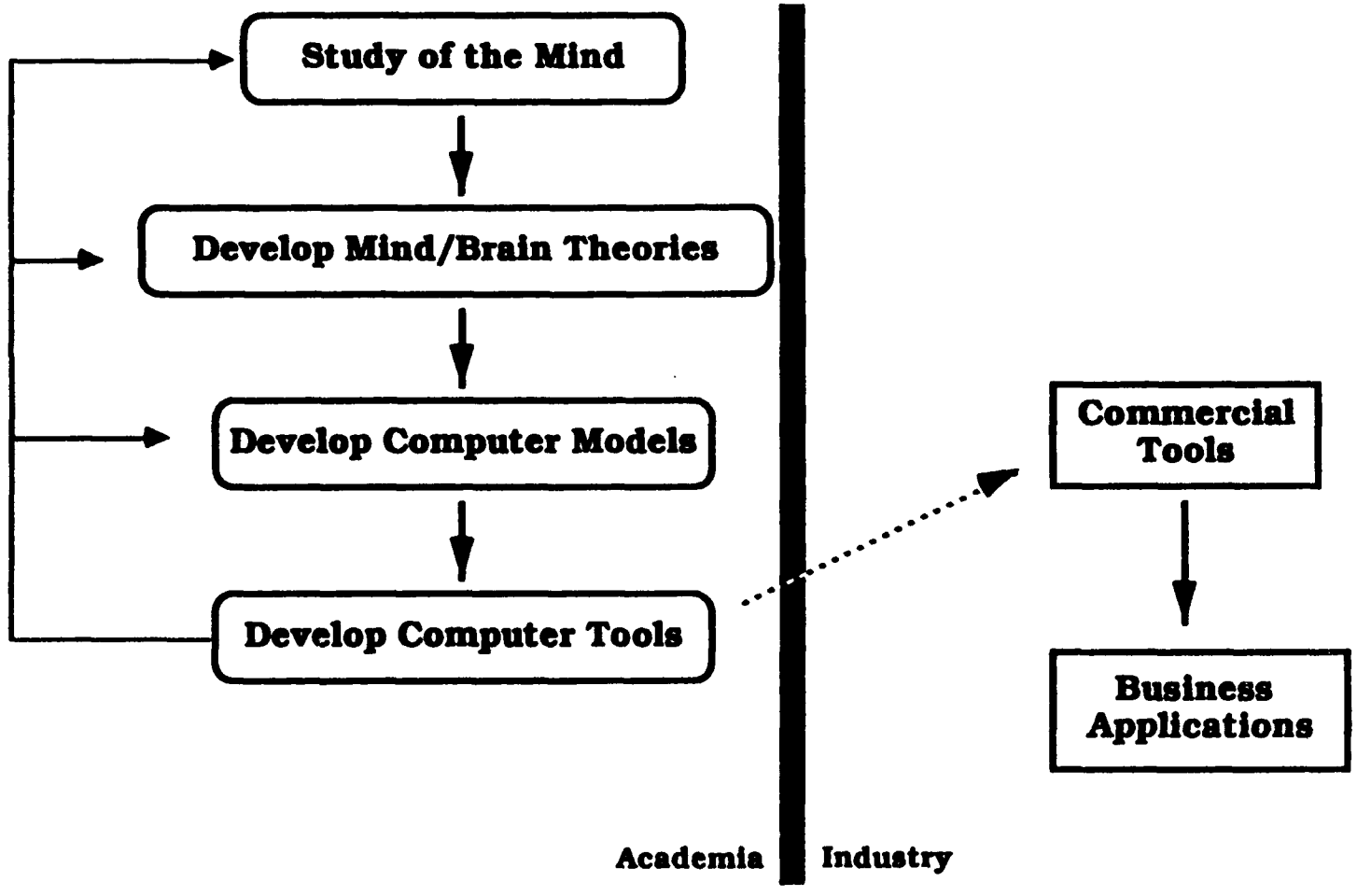
COURSE OBJECTIVES

- **Provide a Framework and Flexible Methodology for Developing Expert/Knowledge-Based Systems**
- **Provide a "Grab Bag" of Tools and Techniques**
- **Demonstrate the Concepts through Case Study Examples and Hands On Exercises**
- **Introduce the Cognitive Aspects of Artificial Intelligence**
- **Promote a New Way of Thinking -- *gestalt shift***

HISTORY OF ARTIFICIAL INTELLIGENCE

EVOLUTION OF "ARTIFICIAL INTELLIGENCE"



DEFINING AND MEASURING HUMAN INTELLIGENCE

DARWIN:
"Evolution is the survival of the fittest"

MODERN INTELLIGENCE TESTS

TERMAN:
STANFORD-BINET INTELLIGENCE TEST

BINET-SIMON INTELLIGENCE TEST

GALTON:
"Fittest means intellectually gifted"

BINET:
Physical measurements

PROGRESS

TIME

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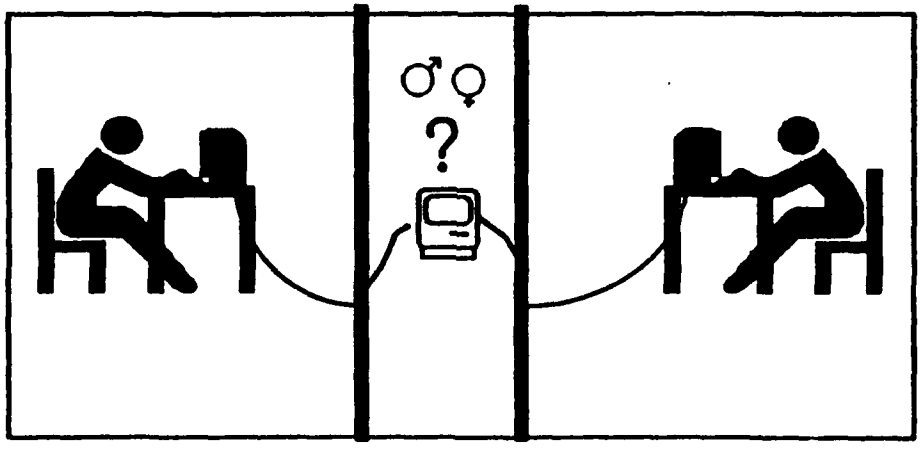
WHAT DO TODAY'S TESTS MEASURE?

- VOCABULARY
- ANALOGIES
- PICTURE COMPLETION
- ABILITY TO REASON
- MEMORY
- IDENTIFY SIMILARITIES
- ABILITY TO FORM CONCLUSIONS
- IDENTIFY PATTERNS
- IDENTIFY ANOMALIES

THE TURING TEST

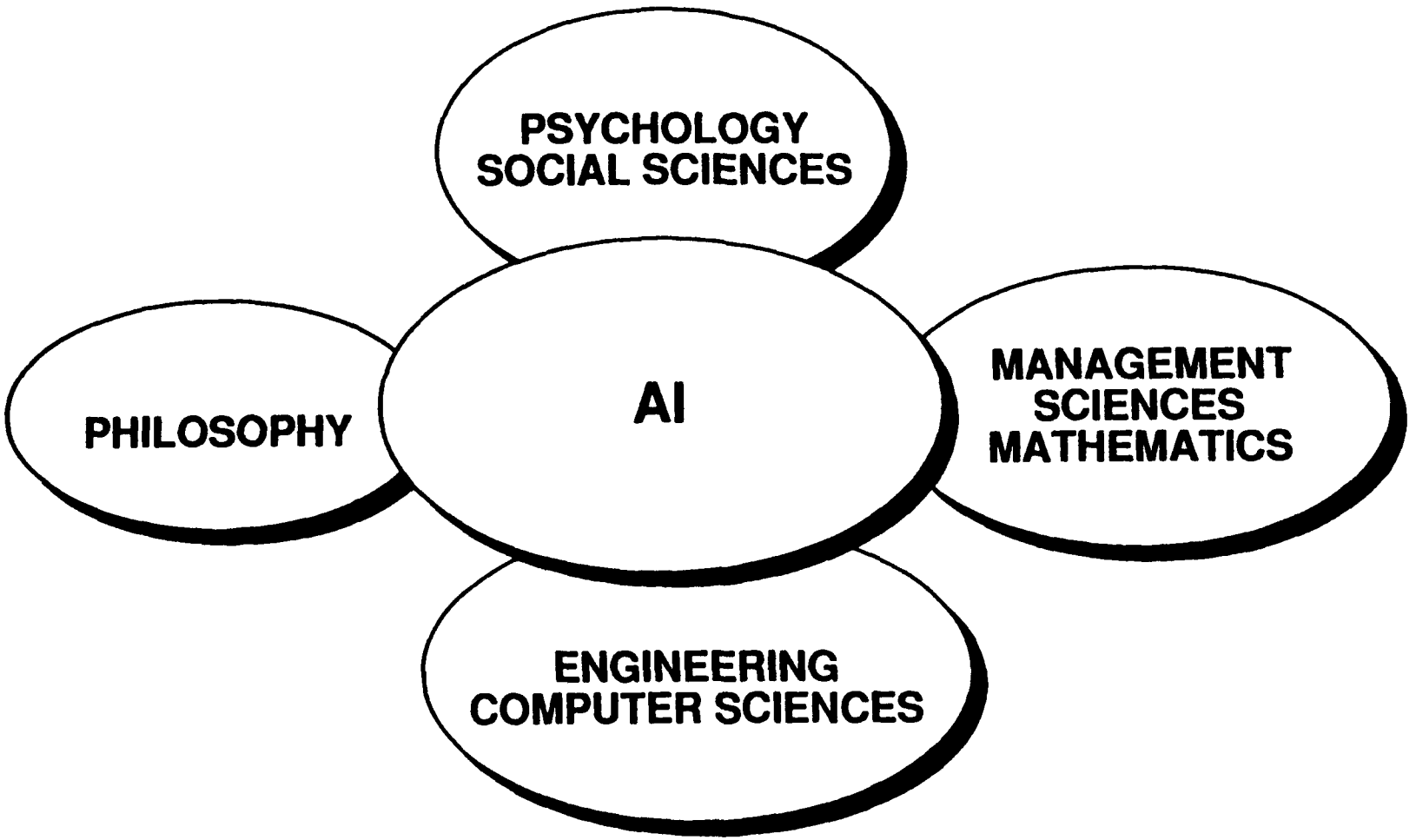
- **Alan Turing - British mathematician and logician**
- ***Computing Machinery and Intelligence***
- **"Can a machine think?"**



THE DARTMOUTH CONFERENCE

- John McCarthy (Father of AI) and Marvin Minsky proposed a two-month, ten-man study during summer of 1956 at Dartmouth College.
- Origin of the term "artificial intelligence"
- Spin-off of conference: groups at M.I.T., Stanford, and Carnegie Mellon

ACADEMIC DISCIPLINES



FIELDS OF ARTIFICIAL INTELLIGENCE

- KNOWLEDGE-BASED/EXPERT SYSTEMS
- NATURAL LANGUAGE PROCESSING
- SPEECH RECOGNITION AND SYNTHESIS
- MACHINE VISION
- ROBOTICS
- MACHINE LEARNING

KNOWLEDGE-BASED vs. CONVENTIONAL SYSTEMS

CONVENTIONAL SIMILARITIES

APPROACHES

- **Multistage Software Development Practices**
- **Project Planning, Management, and Control**
- **Verification and Validation Procedures**
- **User Training**
- **System Start-up and Cut-over**
- **System Maintenance**

TECHNIQUES

- **Mathematical Modeling**
- **Computer Network Architectures**
- **Man-Machine Interfaces**
- **Drivers and Device Interfaces**

KNOWLEDGE-BASED vs. CONVENTIONAL SYSTEMS

ADVANCED CONCEPT SIMILARITIES

APPROACHES

- **Task Environment Analysis and Modeling.**
- **Evolutionary & Rapid Prototyping and Systems Design**
- **Uaw of Advanced Development Environments (Including CASE)**

TECHNIQUES

- **Computer Graphics and WYSIWYG Interfaces**
- **Object Oriented Programming**
- **Recursion and Iteration**
- **Search Strategies**
- **Computer-based Reasoning Methods**
- **Heuristic Programming**
- **Blackboard Architectures**
- **Parsing and Semantic Structure Interpretation**
- **Automatic Generation of Context Executable Code**
- **Hypermedia**

KNOWLEDGE-BASED vs. CONVENTIONAL SYSTEMS

FUNDAMENTAL DIFFERENCES

APPROACHES

- **Knowledge Codification Process: Elicitation, Analysis, Modeling, and Codification**
- **Expert Reasoning Verification**
- **Knowledge Base Maintenance**
- **Analysis of Cognitive Styles of Experts and Users**
- **System Role (cognitive) within the Task Environment**
- **Knowledge Management**

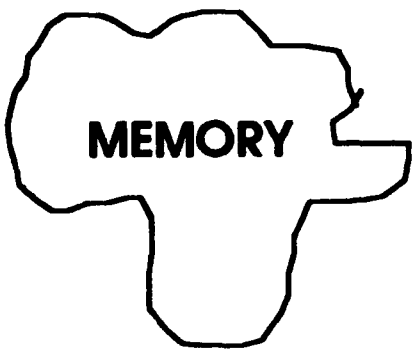
TECHNIQUES

- **Symbolic and Qualitative Reasoning**
- **Interactive Prototyping**
- **Knowledge Technology Approaches**
- **Intellectual Reasoning Strategies**

UNDERSTANDING KNOWLEDGE INTENSIVE ACTIVITIES

KNOWLEDGE

Symbolics Expressions of Things Held In:



RESEARCH FINDINGS ON HUMAN COGNITION
- COGNITIVE STYLES -

TYPES

- **Linguistic**
- **Logical-Mathematical**
- **Spatial**
- **Musical**
- **Bodily-Kinesthetic**
- **Interpersonal**
- **Intrapersonal**

RESEARCH FINDINGS ON HUMAN COGNITION
- KNOWLEDGE -

DOMAINS

- **High Interdependence among Domains**
- **High Interconnectivity among Facts within a Domain**
- **Both can be Integrated into larger units**
  - **chunks**
  - **scripts**
  - **themes**
  - **images**

RESEARCH FINDINGS ON HUMAN COGNITION
- EVOLUTION OF KNOWLEDGE -

PROCEDURAL ⟶ EMBEDDED

- **First Represented Declaratively as Facts**
- **Becomes Proceduralized through repeated uses/practice**
- **Becomes Compiled**
- **Once compiled, not easily verbalized, deleted or modified**

HUMAN MEMORY

PERCEPTUAL MEMORY:

lasts for milliseconds

WORKING MEMORY

lasts for seconds

directly influences bodily movement

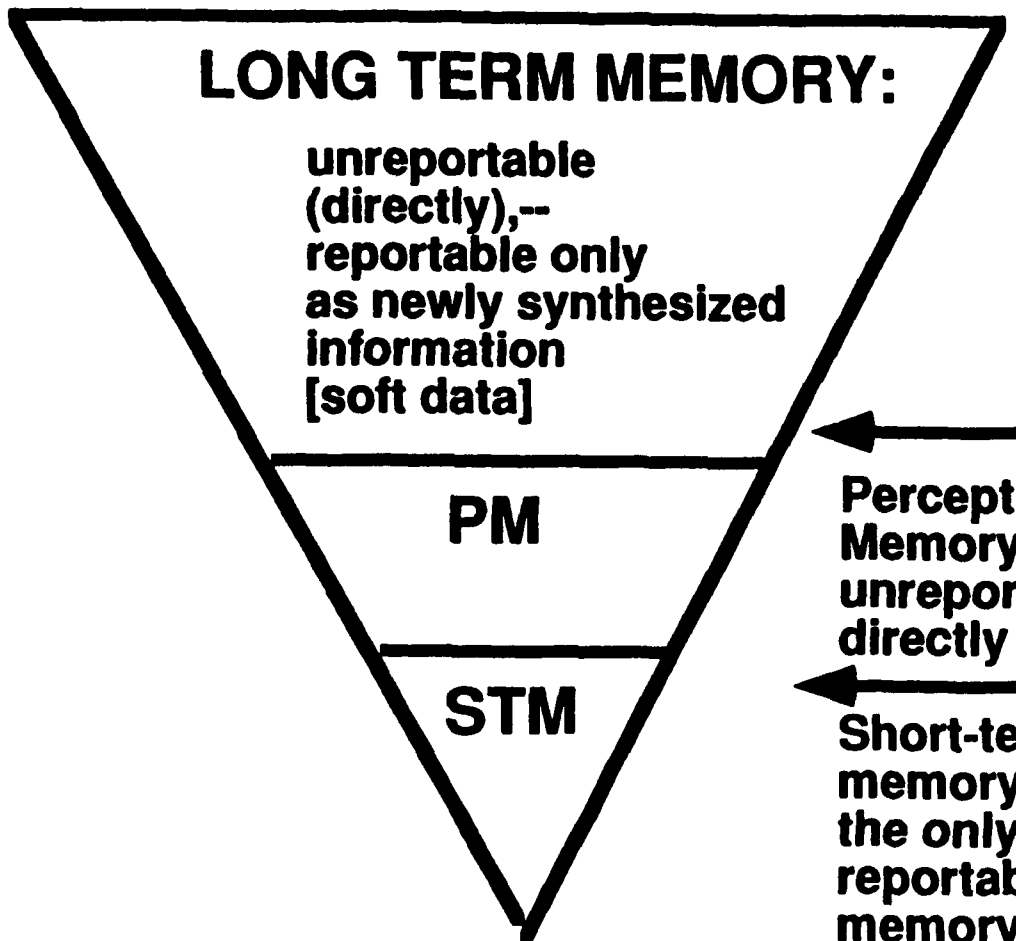
LONG TERM MEMORY

lasts for years

abstracted form of working memory

may influence bodily movement

THE MEMORY TRIANGLE



Perceptual Memory: unreportable directly

Short-term memory: the only directly reportable human memory [hard data]

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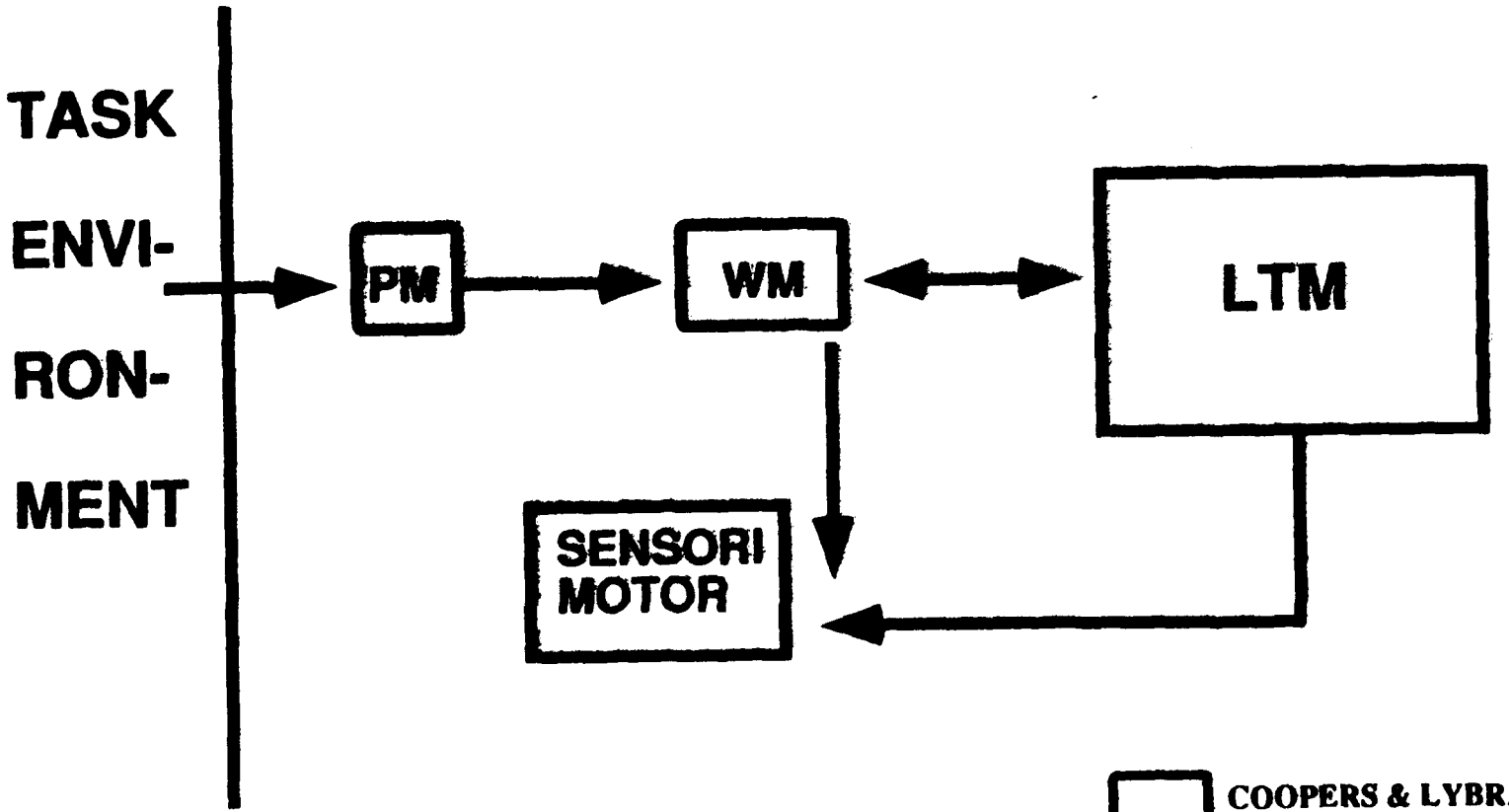
MEMORY MODEL OF HUMAN EXPERT

LEGEND:
PM = Perceptual Memory
WM = Working Memory (Short-term memory)
LTM - Long-term memory



RESEARCH FINDINGS

- **Experts have larger working memories for domain knowledge than novices**
- **Experts are still severely limited in number and complexity of items that can be held in working memory**
- **Constraints on human information processing capacity**

Two Perspectives on Knowledge

COMPETENCE

Knowledge which is:

- **compiled**
- **divorced from its use in time (diachronic)**
- **idealized or abstracted**
- **viewed retrospectively**
- **newly synthesized while elicited**
- **stored in long-term memory**

EXAMPLES OF COMPETENCE KNOWLEDGE

- **Textbooks**
- **Manuals**
- **Descriptions of standard operating procedures**
- **Descriptions of past experiences**

Two Perspectives on Knowledge

PERFORMANCE

Knowledge which is

- **observable in knowledge-intensive activities**
- **executed in real time (synchronic)**
- **specific to an individual**
- **viewed concurrently with task performance**
- **directly reported as it is heeded**
- **stored in short-term memory**

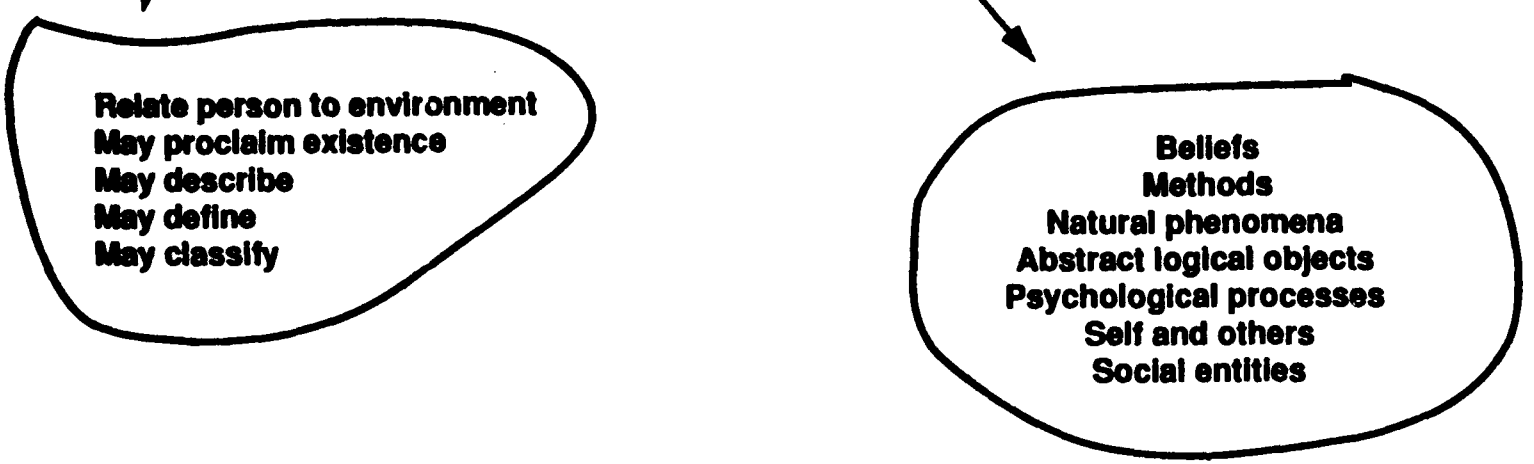
EXAMPLES OF PERFORMANCE KNOWLEDGE

- **"Think-alouds"**
- **Spontaneous expressions of though**
  - **verbal**
  - **physical**
- **Doing a job, performing a task**

UNDERSTANDING KNOWLEDGE

KNOWLEDGE

Assertions about **"objects,"** their properties, states, and relations to other "objects"



KNOWLEDGE DEFINITIONS

KNOWLEDGE IS EXPRESSED IN:

Statements
Actions

→ Theorems, "Commentary", Propositions, Speeches, Articles, Books

Physical, spatial, temporal arrangements of objects
Symbolic Representations of Objects
Practical Activity

→ Designs, Structures, Landscapes

Social Processes and Organization
Culturally valued tasks
Behavior
Mental Constructs

→ Images, Memories, Scripts, Propositions

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TYPES OF KNOWLEDGE

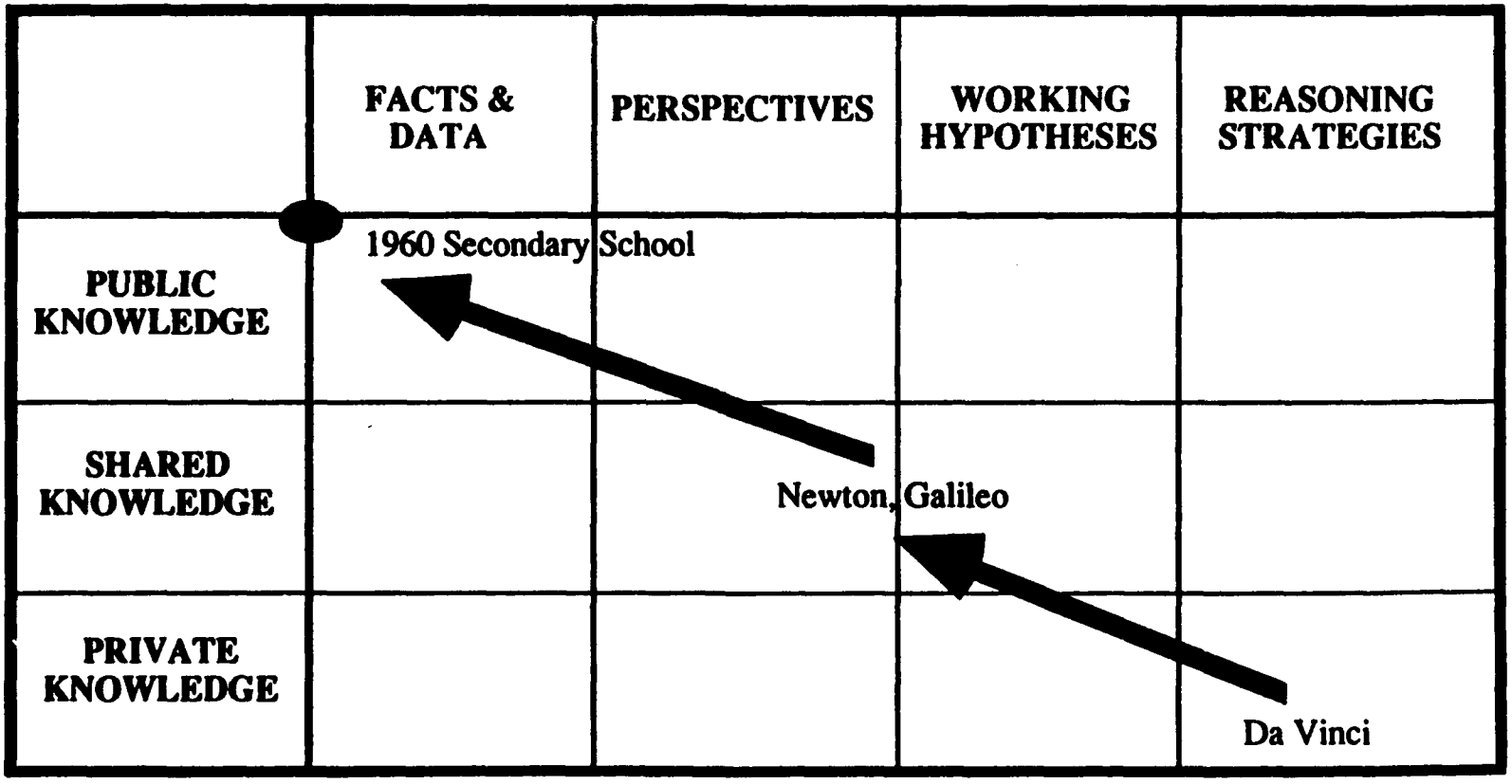
	FACTS & DATA	PERSPECTIVES	WORKING HYPOTHESES	REASONING STRATEGIES
PUBLIC KNOWLEDGE				
SHARED KNOWLEDGE				
PRIVATE KNOWLEDGE				

TYPES OF KNOWLEDGE

	FACTS & DATA	PERSPECTIVES	WORKING HYPOTHESES	REASONING STRATEGIES
PUBLIC KNOWLEDGE	Text Book Knowledge	Generally Accepted Points of View	Typical Hypotheses for Implications of Known Contexts	Strategies Taught in Classrooms
SHARED KNOWLEDGE	Specialized Information for a Particular Field	Perspectives Understood in Particular Situations	Insights into Narrowly Understood Situations	Expert Strategies to: Diagnose Manage Synthesize
PRIVATE KNOWLEDGE	Privately Held Data, Observations and Information	Private Concepts and Gestalts	Expectations, Beliefs and Misconceptions	Intuition

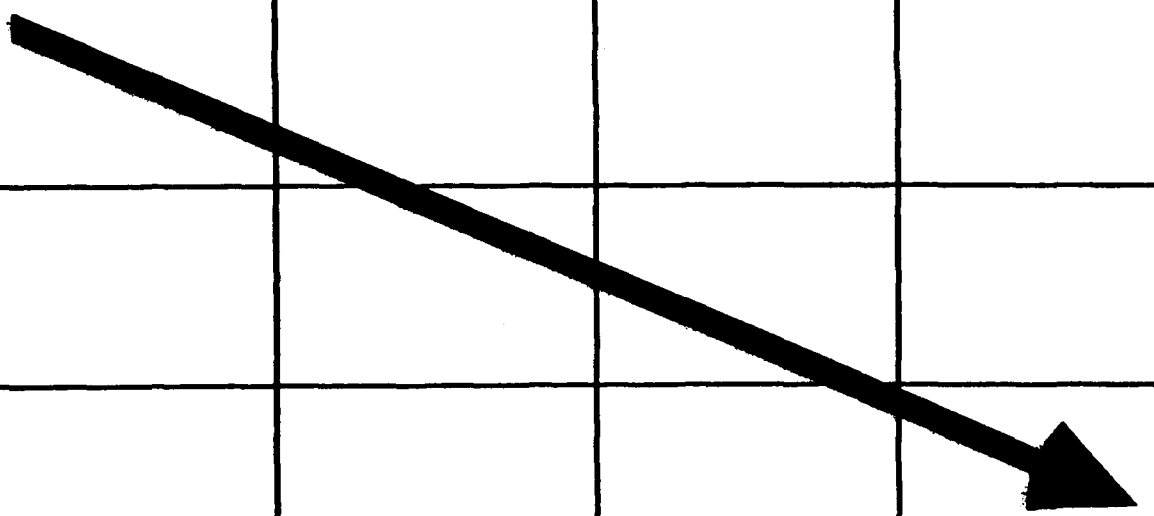
EVOLUTION OF KNOWLEDGE

UNDERSTANDING OF DYNAMICS



EVOLUTION OF AI SYSTEMS

	FACTS & DATA	PERSPECTIVES	WORKING HYPOTHESES	REASONING STRATEGIES
PUBLIC KNOWLEDGE				
SHARED KNOWELDGE				
PRIVATE KNOWLEDGE				



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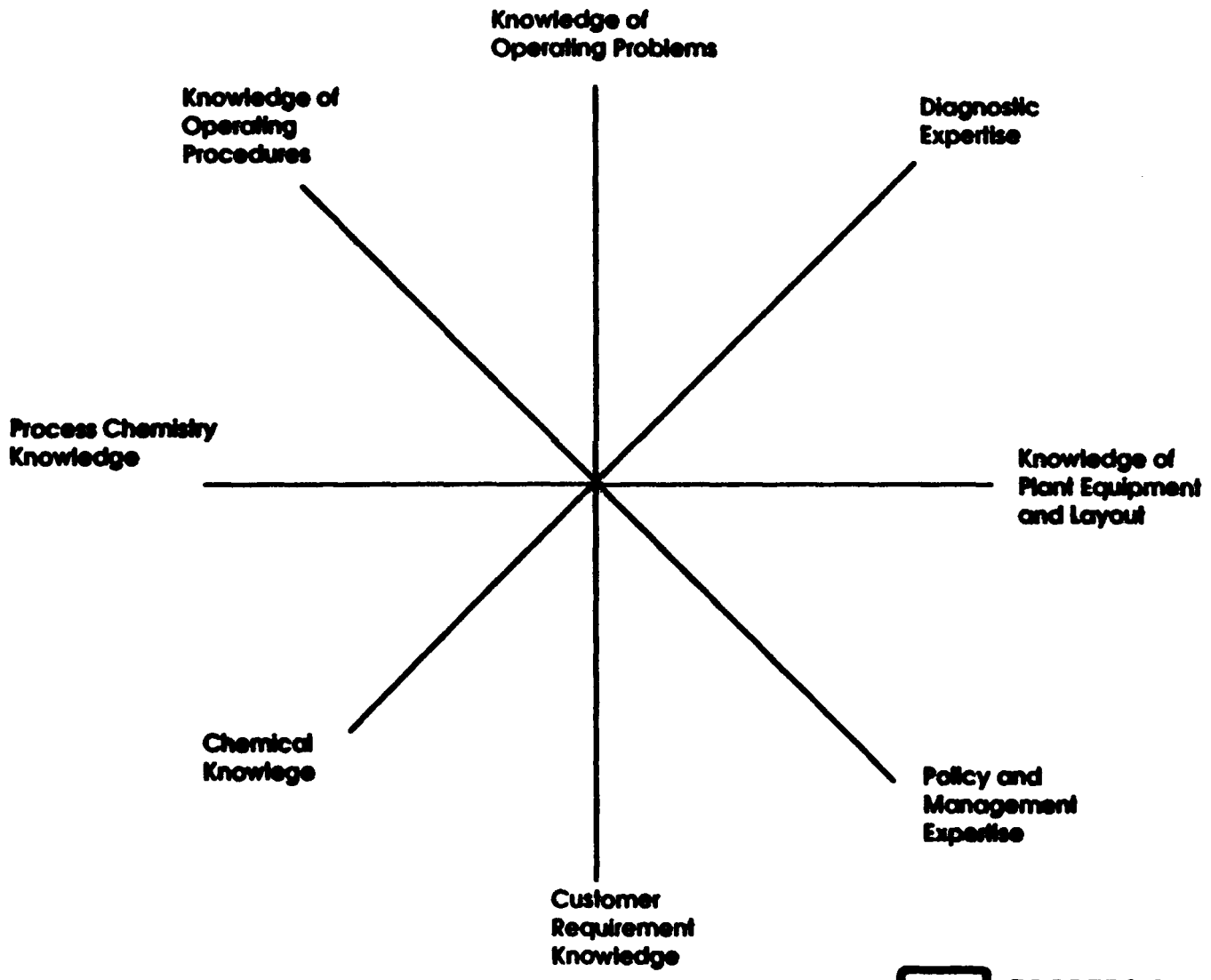
EXPERTISE

- **High Performance**
- **Ability to Find Acceptable Solutions Efficiently**
- **Ability to Reduce Complexity**
- **Use of Failure Strategies**
- **Ability to Explain**
  - **how a conclusion was reached**
  - **why a particular piece of information is needed**
  - **why a particular conclusion was not reached**
- **Meta-Knowledge**

DIMENSIONS OF EXPERTISE



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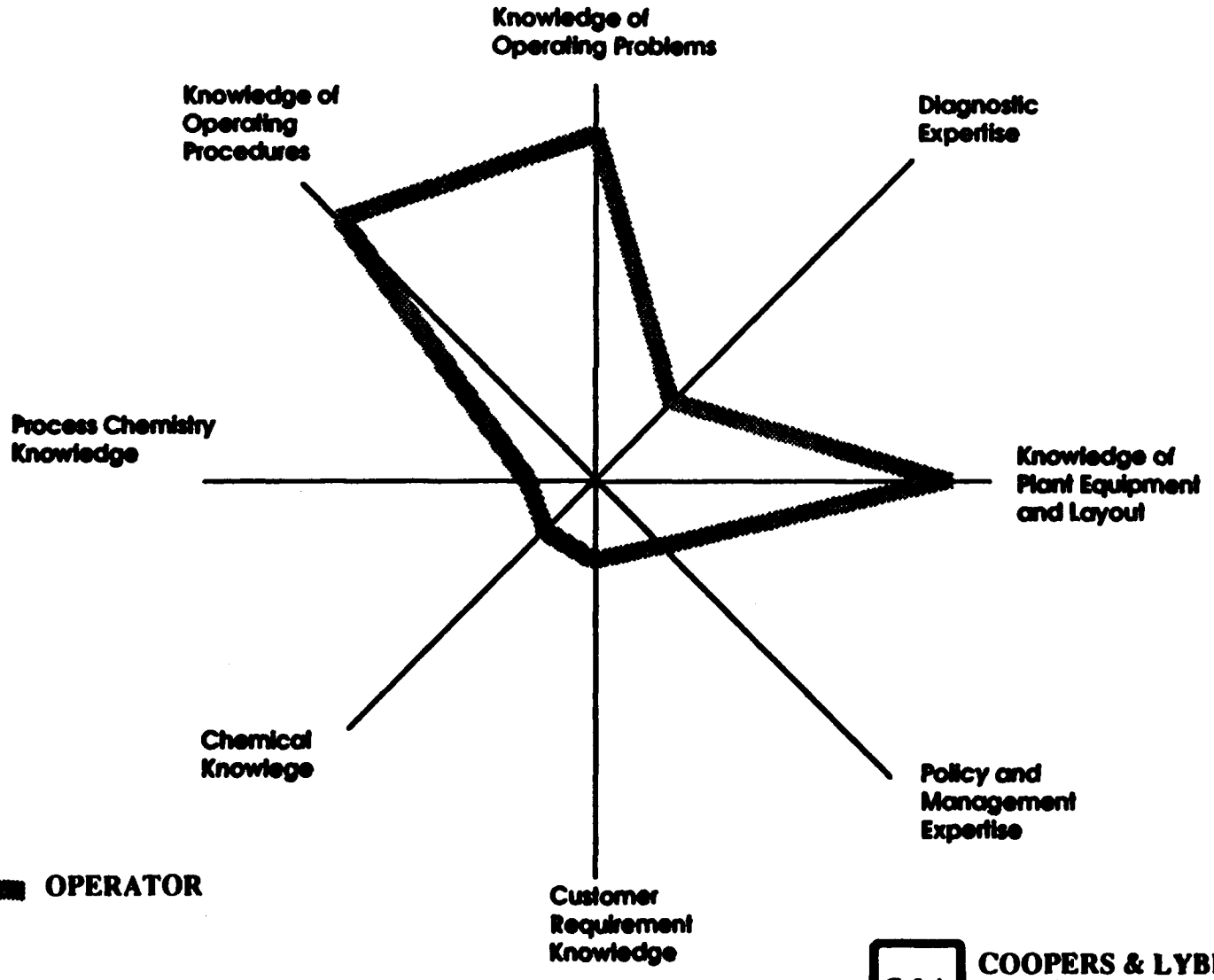
DIMENSIONS OF EXPERTISE



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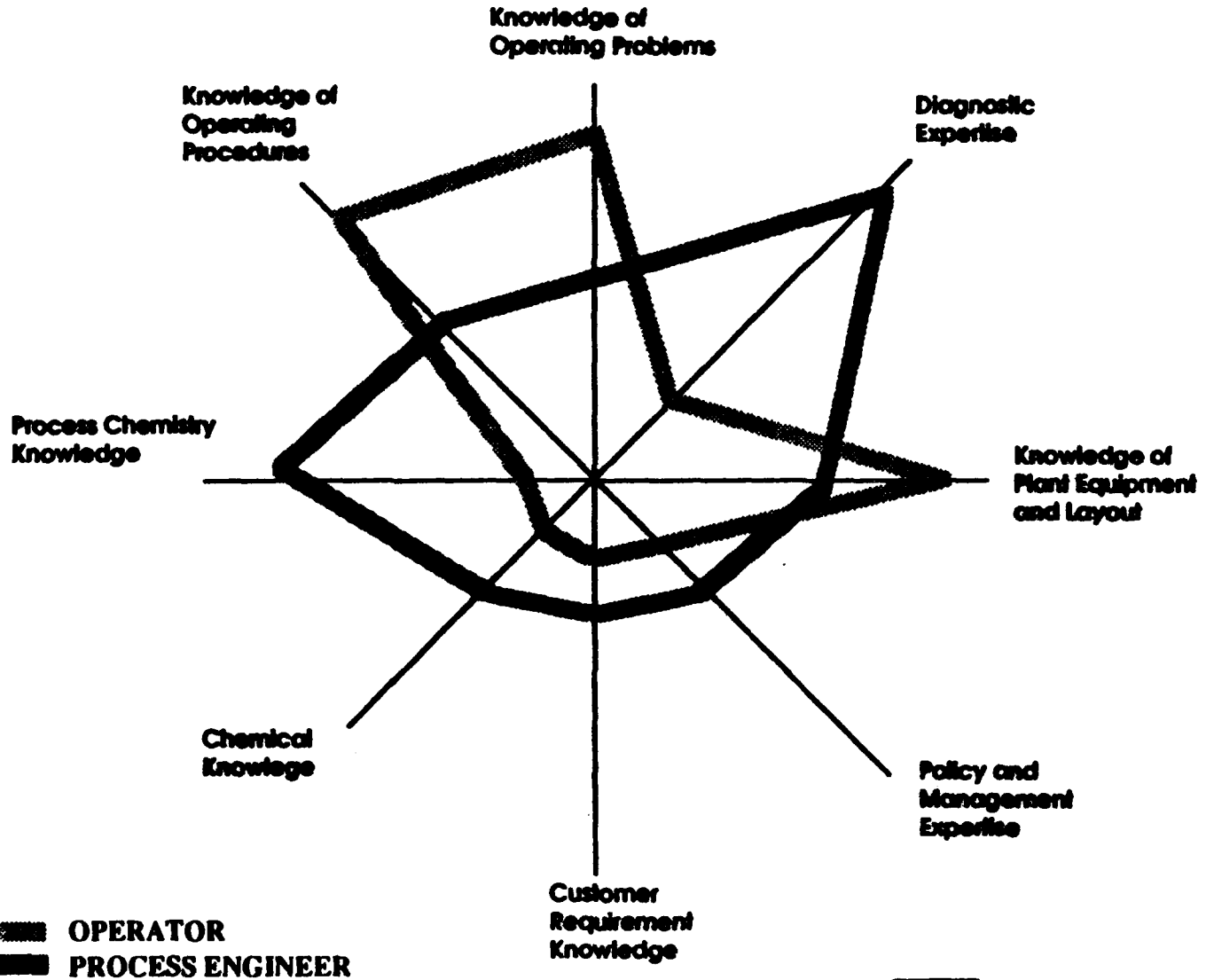
DIMENSIONS OF EXPERTISE



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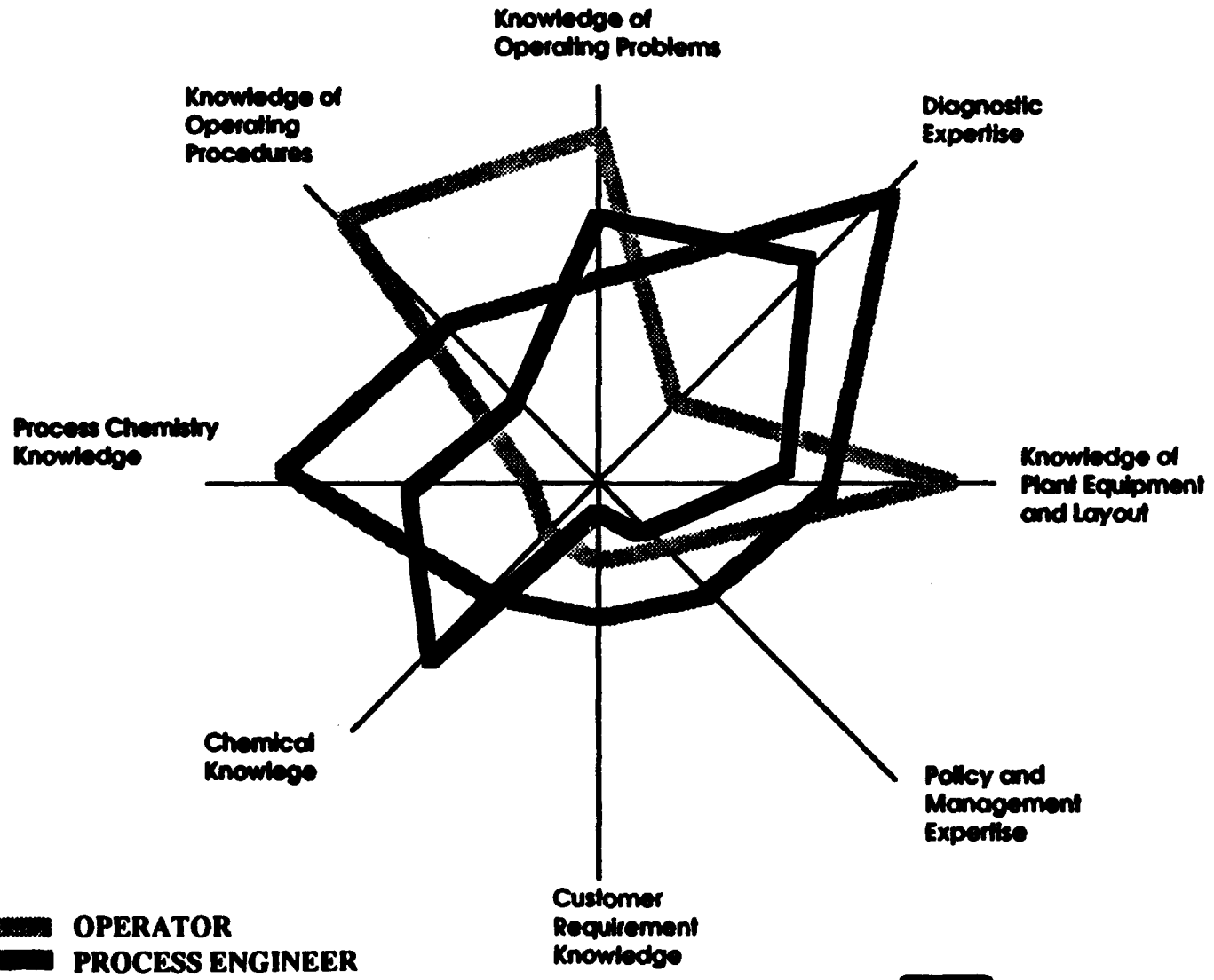
COMPLEMENTING EXPERTISE WITH A SYSTEM



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CORPORATE KNOWLEDGE

- **The unique history of a firm in a particular industry**
- **Individual work histories of the current employees**
- **Mixture of public, shared, and private knowledge**
- **Developed over a long time in a variety of situations**
- **Tested by practice**
- **Dispersed, miscellaneous unstructured, unrecorded**
- **"Thrown together"**

The company's most valuable asset is also the hardest to manage and exploit!

KNOWLEDGE AS A COMMODITY

The knowledge of the workforce and its managers is just as valuable to a corporation as capital equipment;

However, less attention is paid to inventorying and preserving this valuable but intangible commodity.

The judicious use of AI technology offers the opportunity to:

- **CAPTURE**
- **STRUCTURE**
- **PRESERVE**
- **ENHANCE**

<u>CORPORATE</u> knowledge!

UNDERSTANDING REASONING

Reasoning is:

- the movement of the mind from premises to conclusions
- not performed in a vacuum
- a mental process worked through via materials of some sort
- a mental process for which materials provide the context

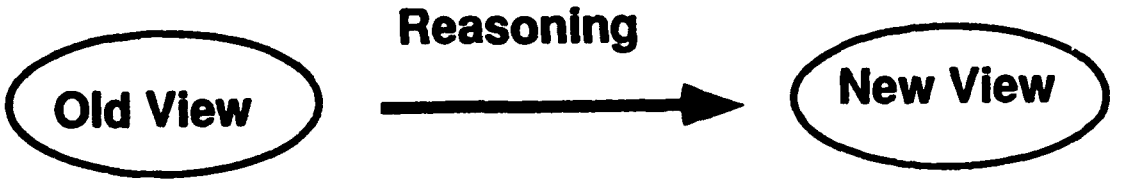
REASONING IN CONTEXT

- Materials are essential because
  - they act as triggers
  - they serve as external memories of
    - what I know
    - what I should know
    - what I have figured out so far
  - they support navigation through a task

LOGIC AND REASONING

Logic = primarily deductive argument
monotonic

Reasoning = induction, abduction, imagistic operations ...
nonmonotonic



DEDUCTION

- a form of argument in which the conclusion follows with certainty from the premises

Example :

All experienced plant operators have knowledge learned on the job

Joe is an experienced plant operator

Therefore Joe has knowledge learned on the job

DEDUCTION

Most AI tools support deduction

e.g. forward and backward chaining

Example:

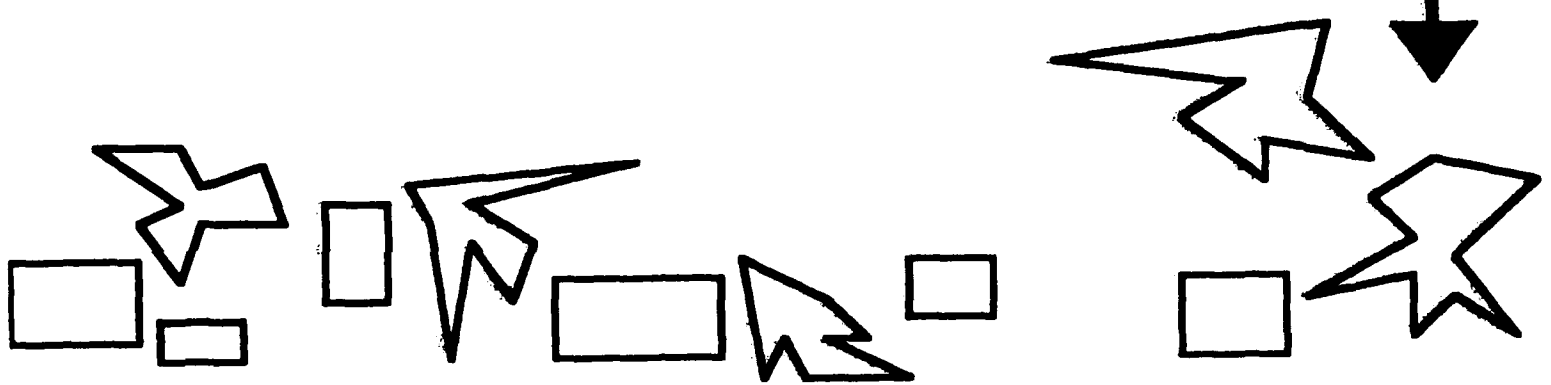
If someone is an experienced plant operator,

then that person has knowledge learned on the job

Assert: Joe is an experienced plant operator

General Assumptions or
Conclusions
all x's are y's

Deduction



Representations of particular things and events

INDUCTION

- a form of argument in which the conclusion follows probablistically from the premises

Example:

Last week, when a drop in the price of oil was announced, the price of General Motors stock increased.

Yesterday, when a drop in the price of oil was announced, the price of General Motors stock increased.

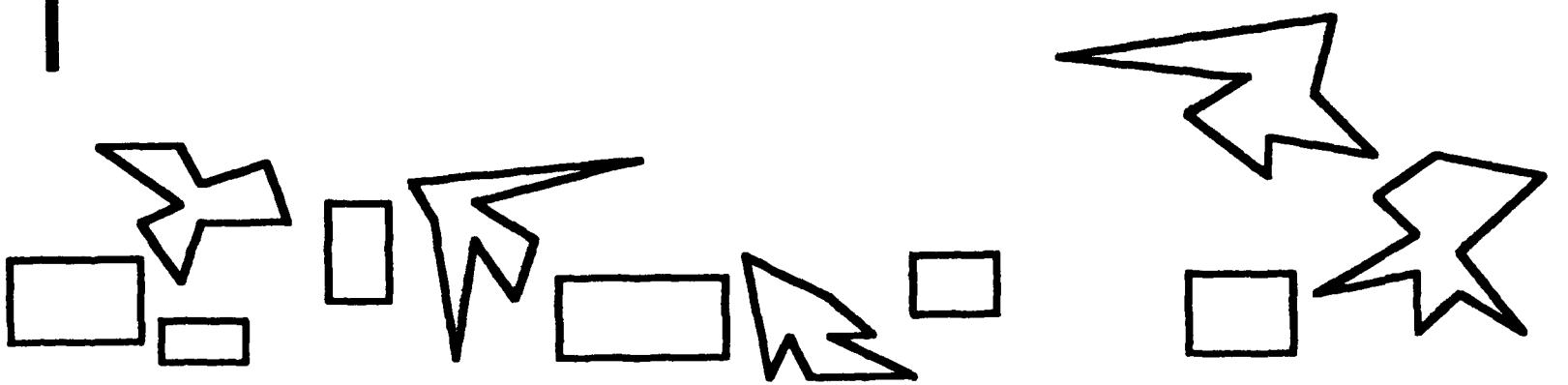
A drop in the price of oil has just been announced.

I conclude that the price of General Motors stock will increase.

General Assumptions or Conclusions

all x's are y's

Induction



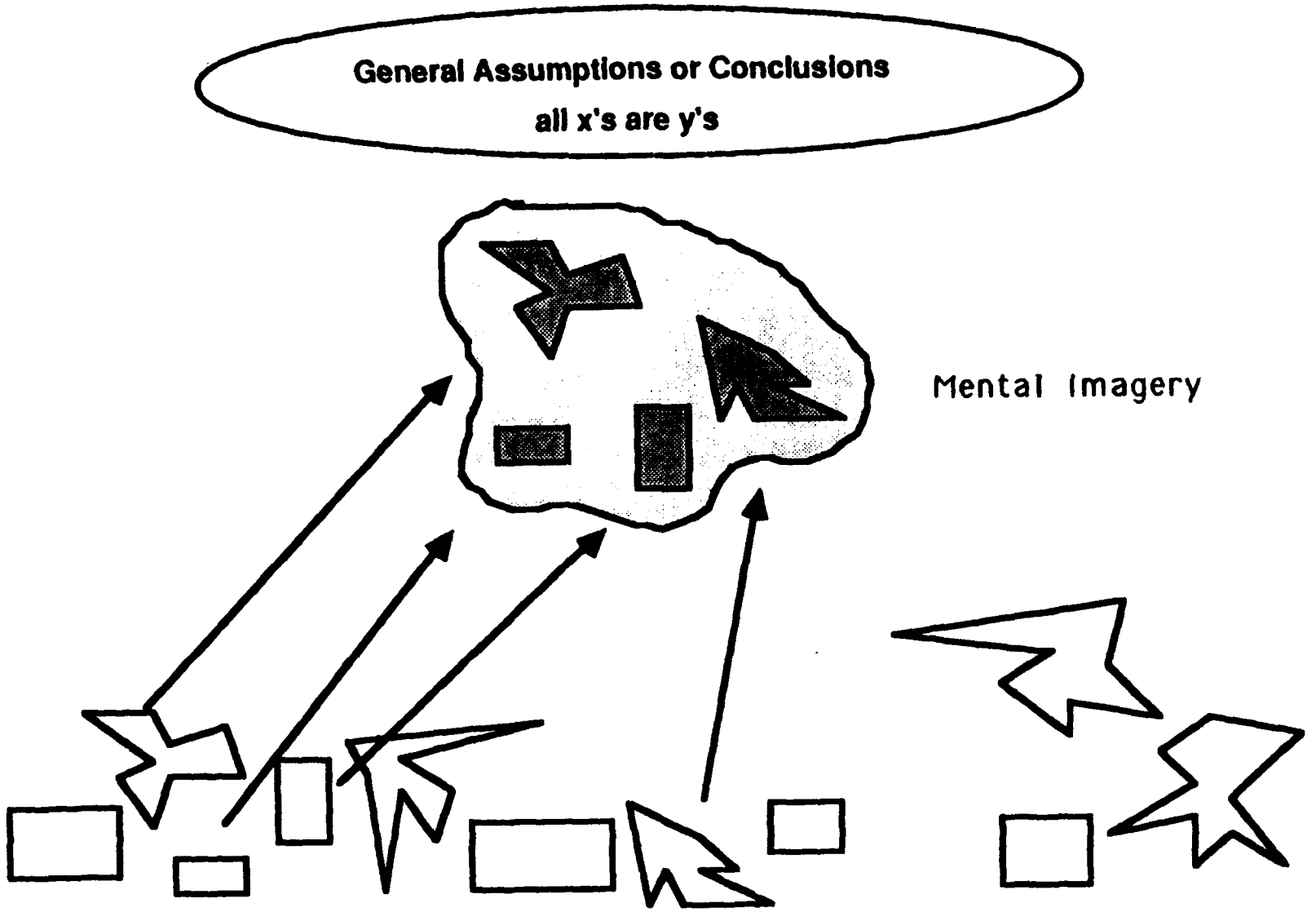
Representations of Particular things and events

MENTAL IMAGERY

- **Internal pictorial representations are manipulated**

Example:

- **the foreman in a manufacturing cell who has the "big picture"**



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ANALOGY

- Things or events known to be alike in some respects are inferred to be alike in other respects

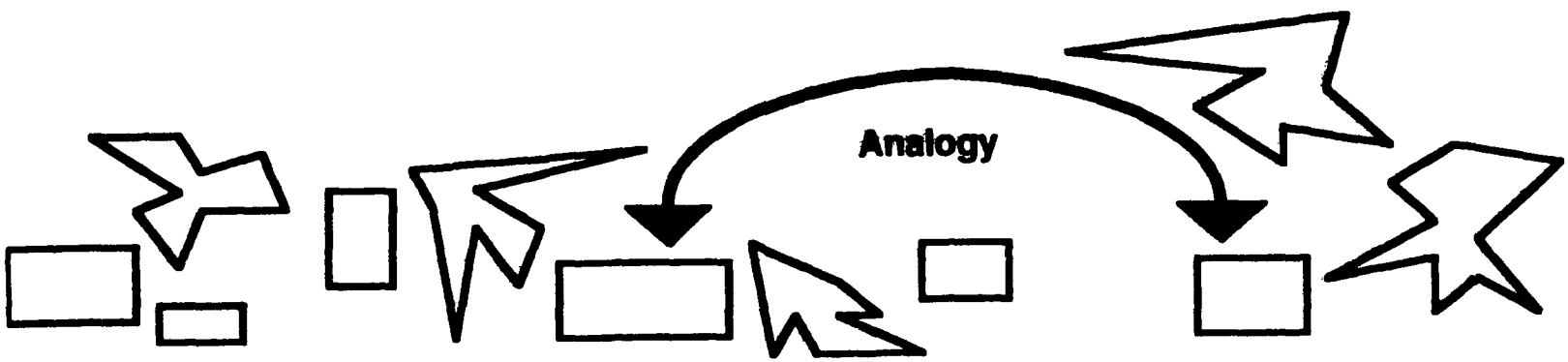
Example:

- Cost estimators for major defense programs look for a similar program, and tailor their current estimate to that program

... " this program is like that one in some respects, so I'll assume it like that one in all respects"

General Assumptions or Conclusions

all x's are y's"



Representations of Particular things and events

STORY WEAVING

- **Selective remembrances of events are used to understand current events**

Example:

  - **NASA weather forecasters, who explain today's weather by telling a story about a significant weather event that happened in the past**

METAPHOR

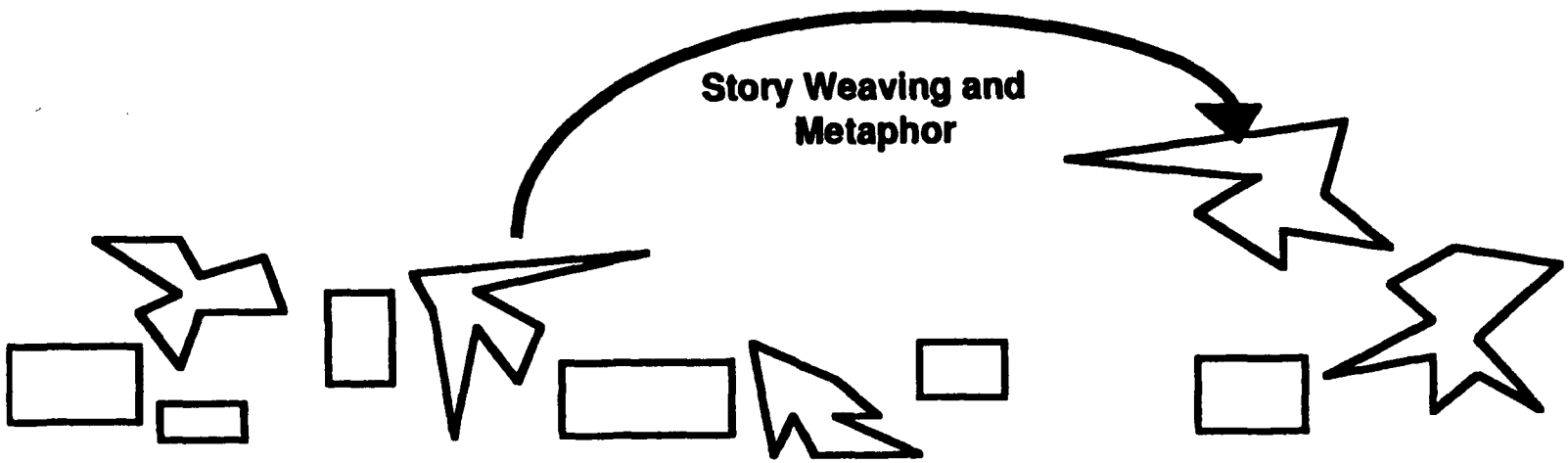
- Terms referring to one domain are used to understand another domain

Example:

- alkylation plant operators who view the plant as an organism

"She's getting jittery now"

General Assumptions or Conclusions
all x's are y's"



Representations of Particular things and events

TRIAL AND ERROR APPROACHES

- **Organizing and conducting "experiments" that put questions to the world**

Examples:

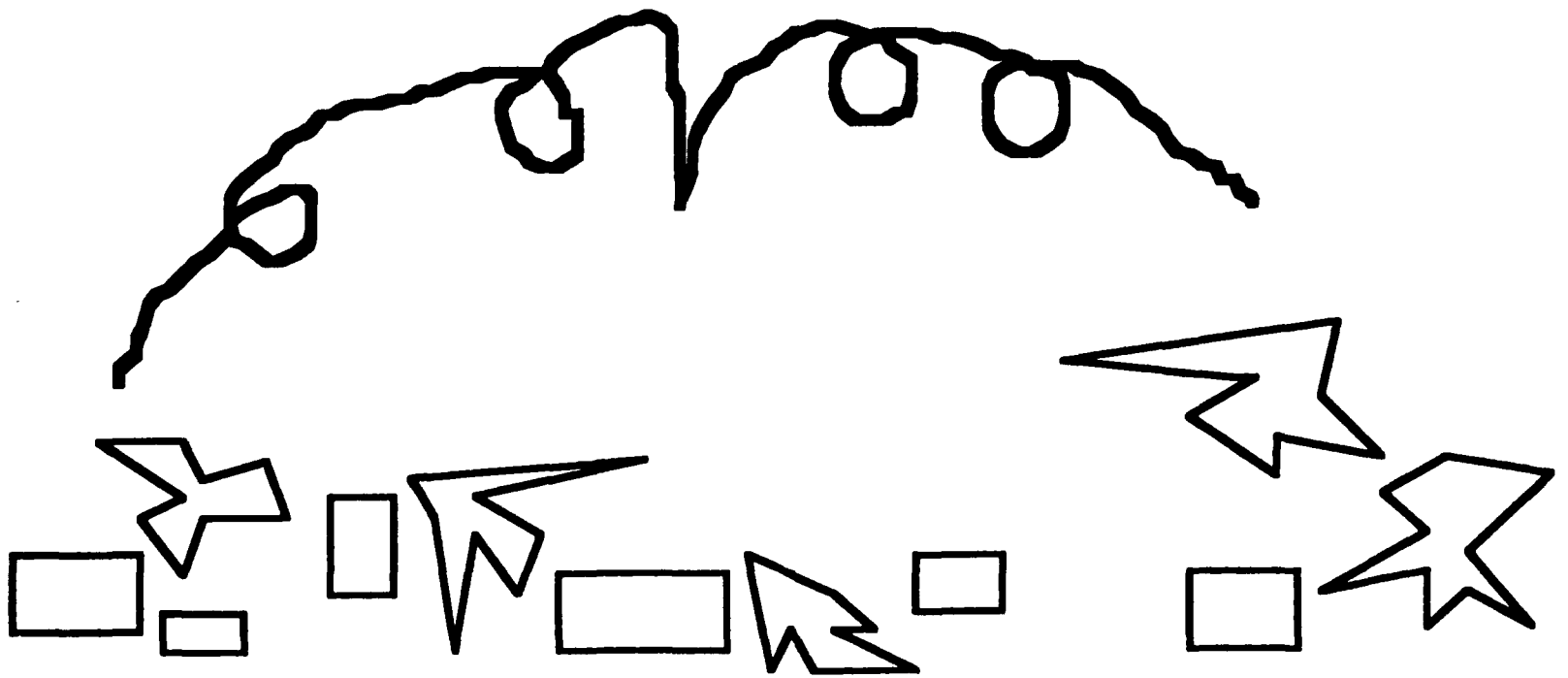
Thought experiments

Systematic and unsystematic grouping

What-if games

General Assumptions or Conclusions
all x's are y's"

Trial and Error Approaches



Representations of Particular things and events

ABDUCTION

- a form of inference which results in the generation of a hypothesis
- working from what we want to explain to that which would explain it

The process:

Study the "facts"

Devise a hypothesis, H, to explain the facts

This involves an original suggestion or idea

If H were true, the facts would be explained

Therefore, there is reason to think that H is true

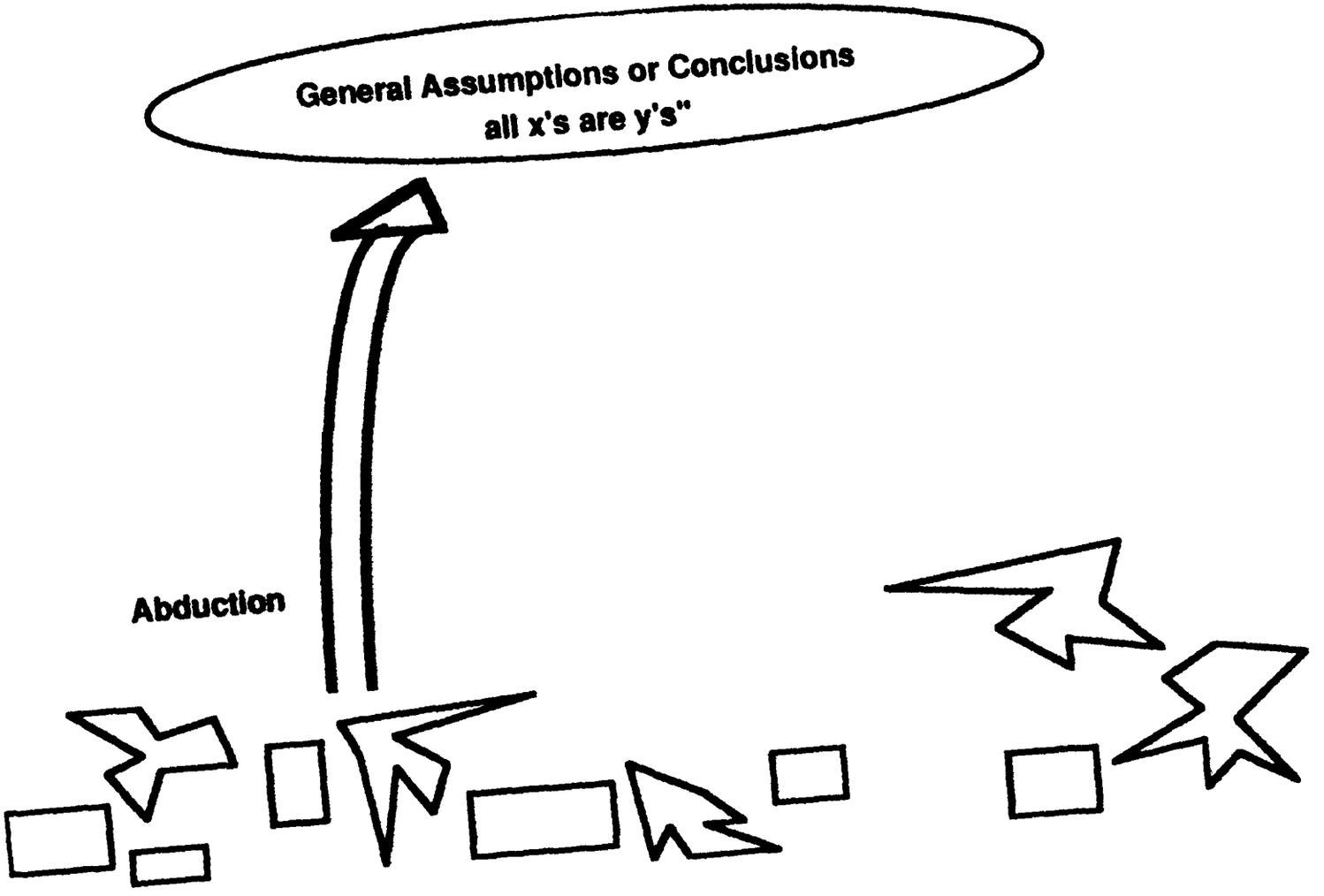
ABDUCTIVE INFERENCE

Constraints on abductive inference

- **Logic**
- **Our knowledge of cognitive psychology**
- **Our understanding of social and physical reality**

The justification of abductive inference

- **"The only justification is the justification of desperation"**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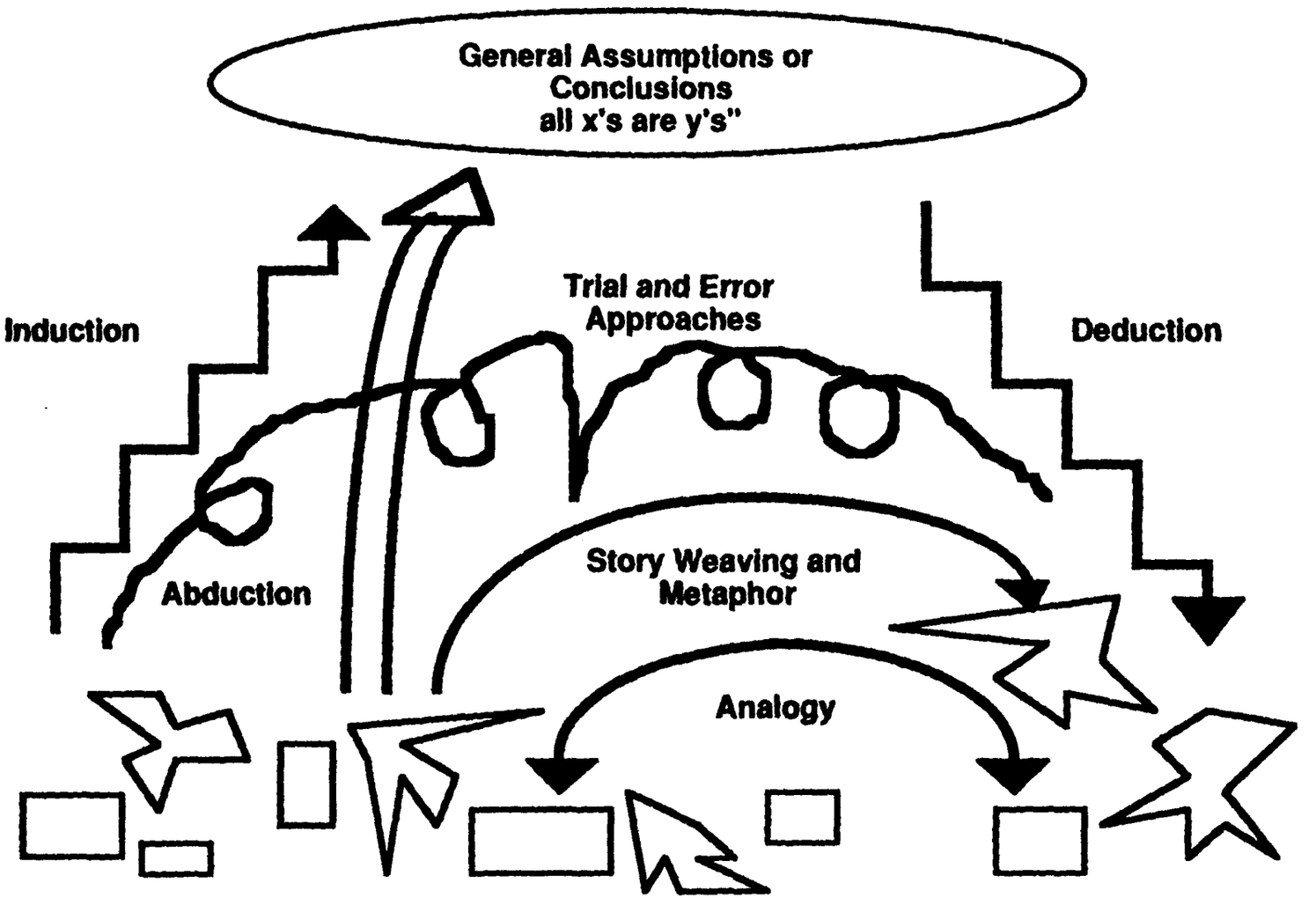
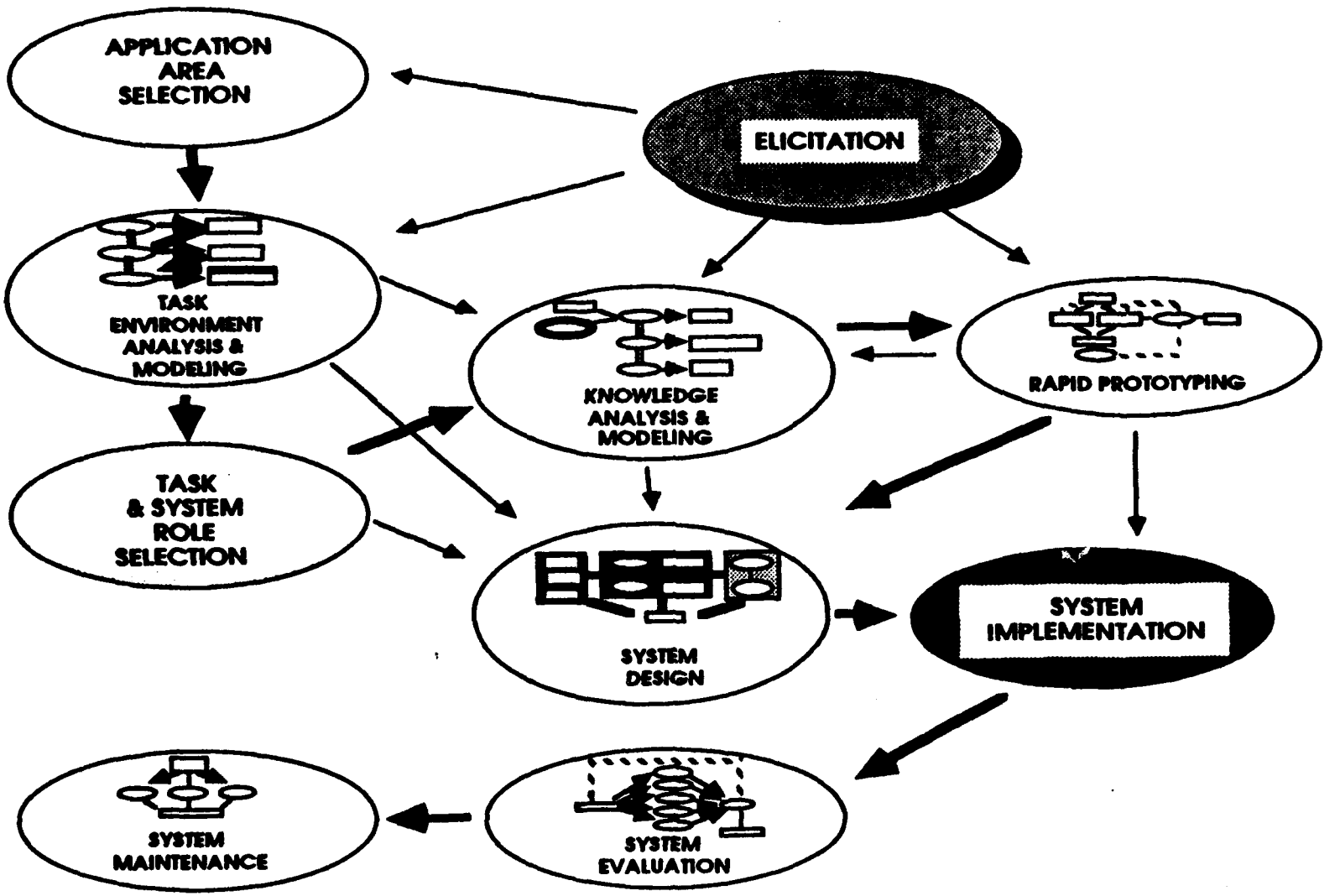

General Assumptions or
Conclusions
all x's are y's"
Induction
Trial and Error
Approaches
Deduction
Abduction
Story Weaving and
Metaphor
Analogy
Representations of Particular things and events

PREVIEW OF THE METHODOLOGY

DETAILED METHODOLOGY



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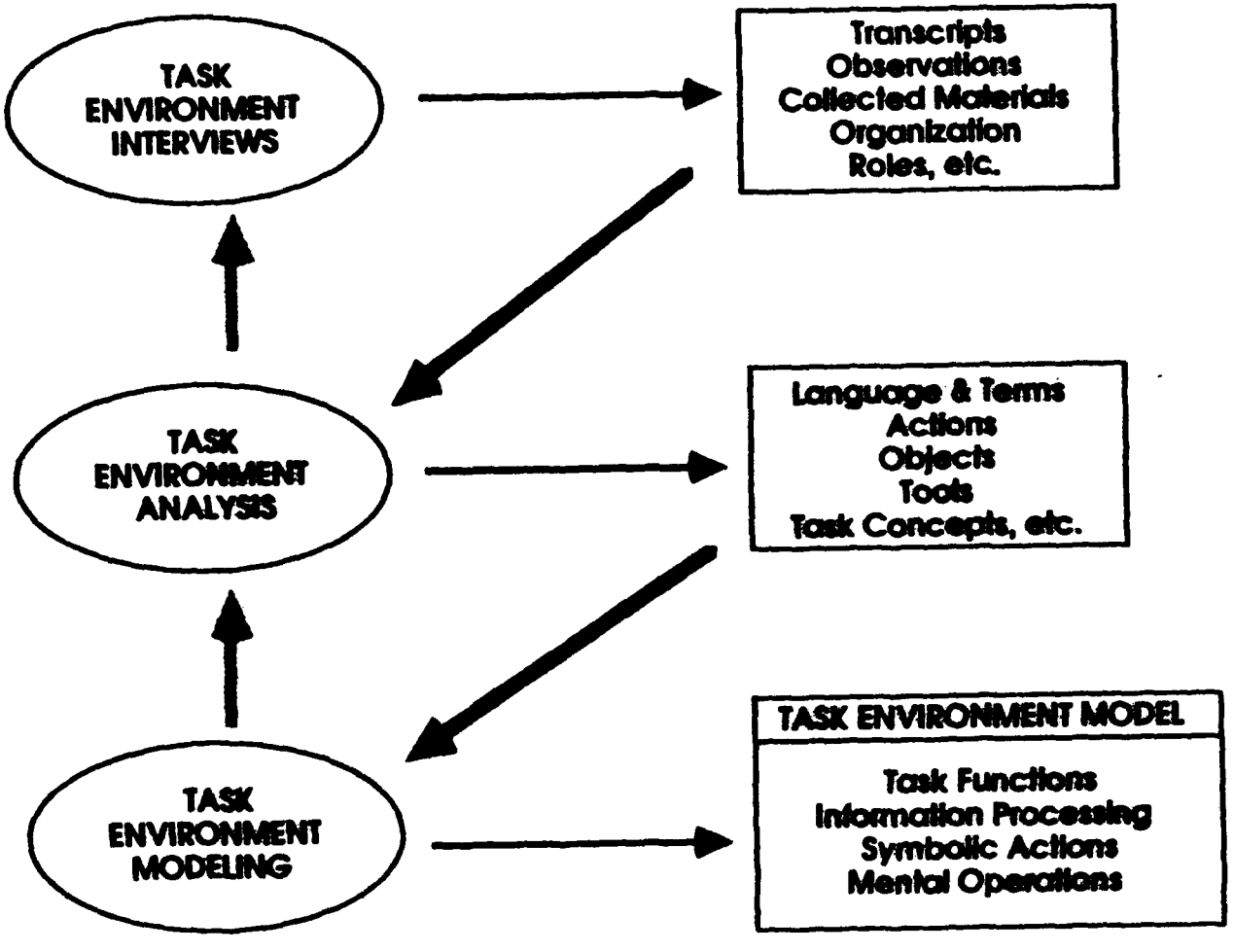
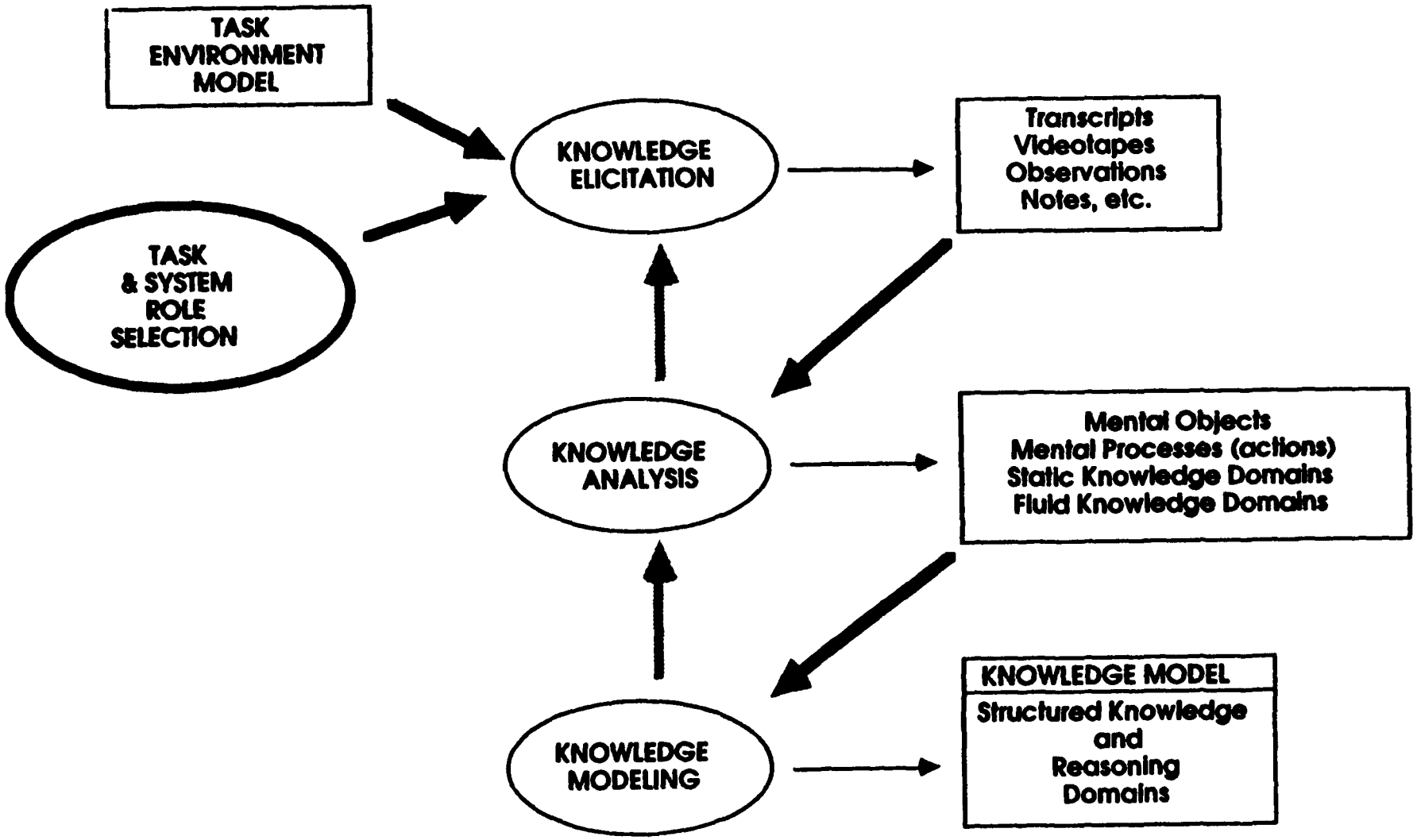
TASK ENVIRONMENT ANALYSIS & MODELING



KNOWLEDGE ANALYSIS AND MODELING



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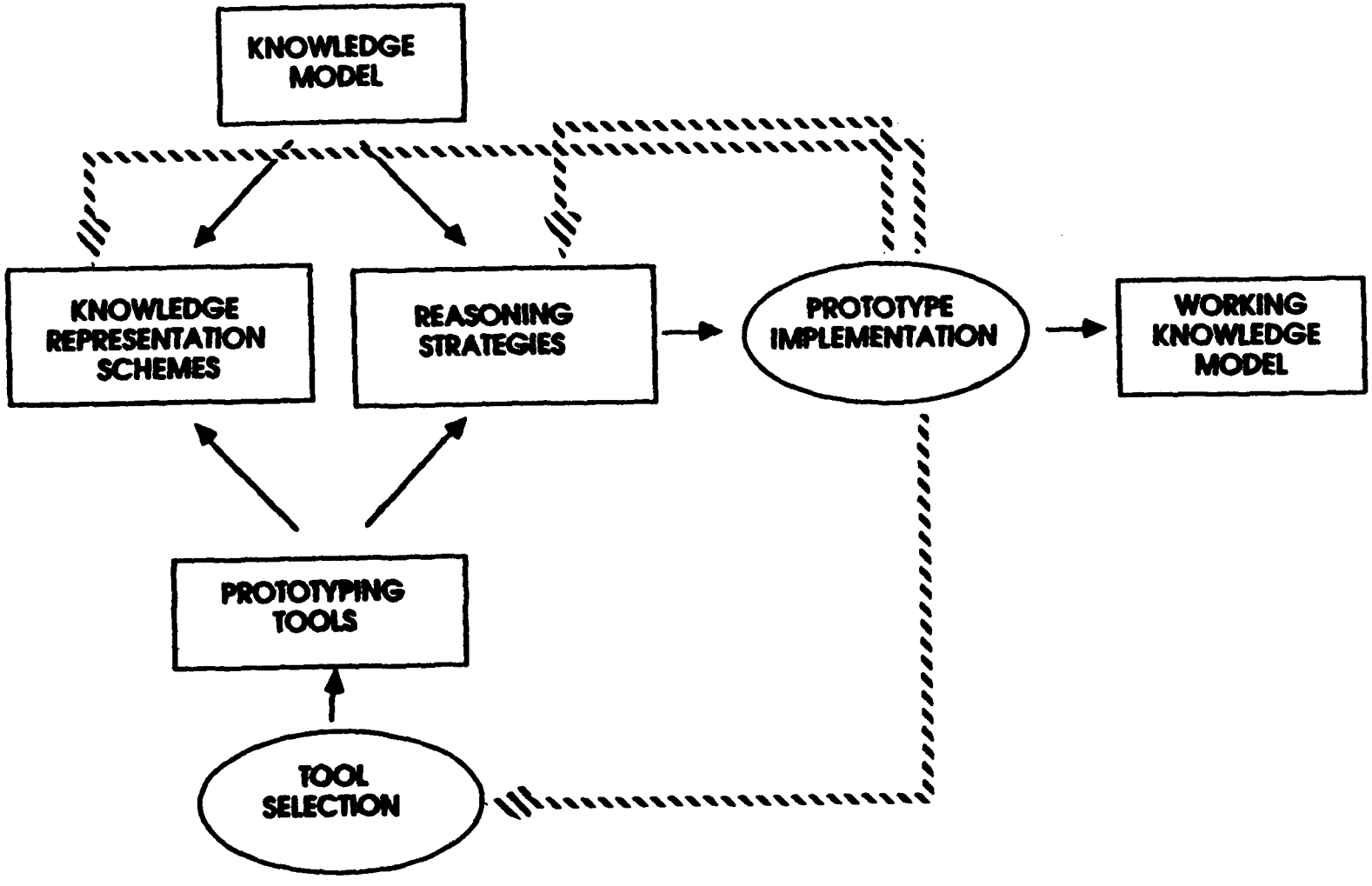
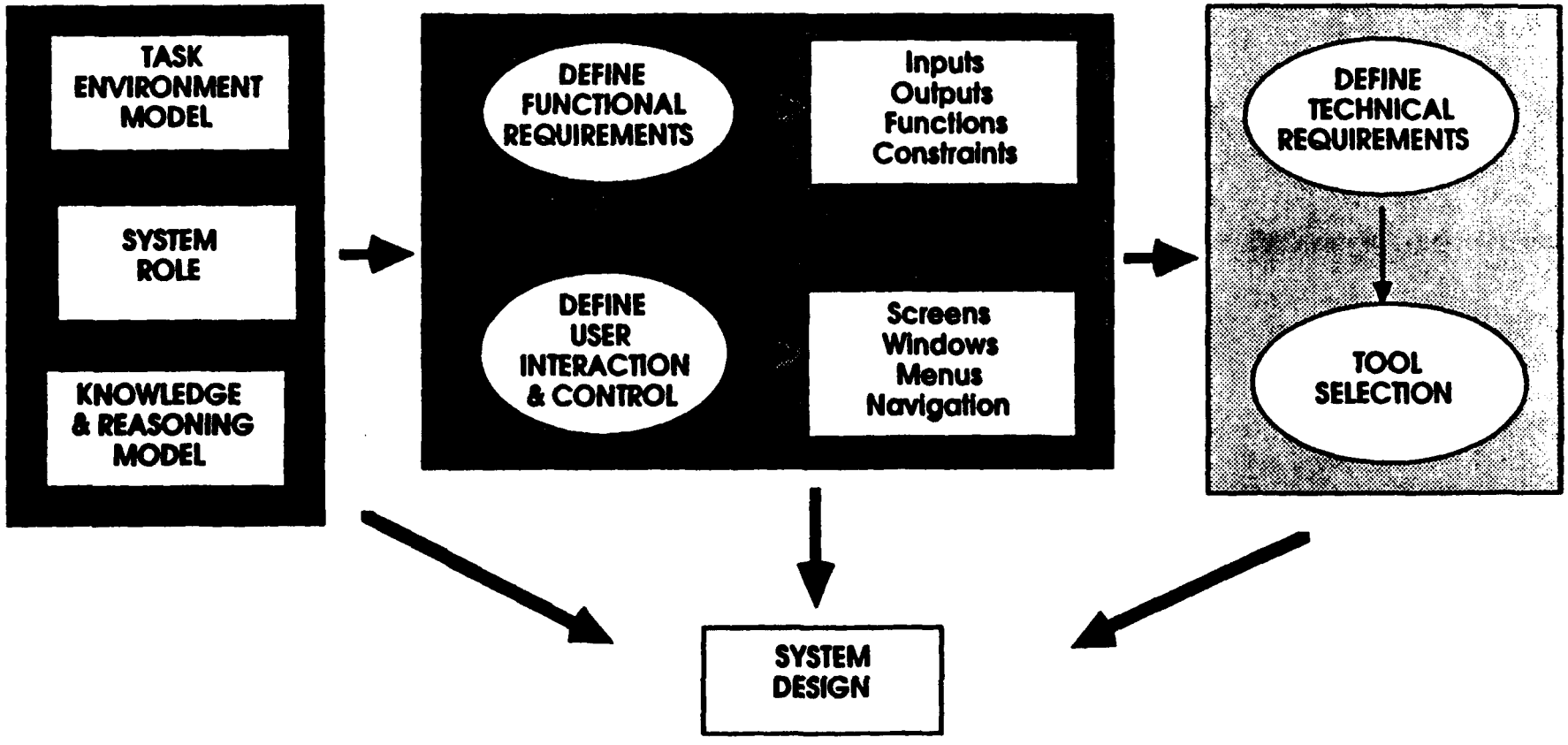
RAPID PROTOTYPING



SYSTEM DESIGN



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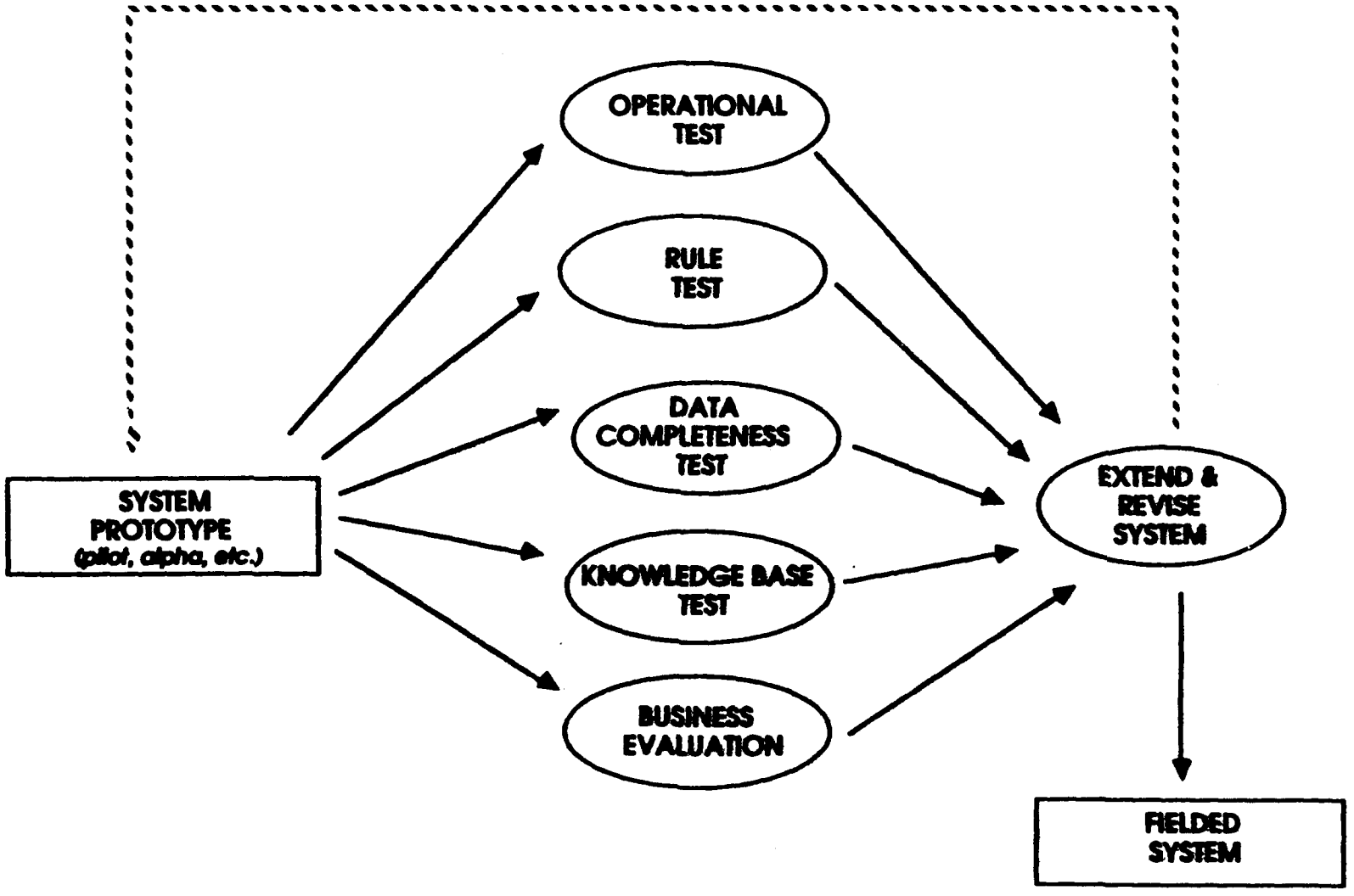
SYSTEM EVALUATION



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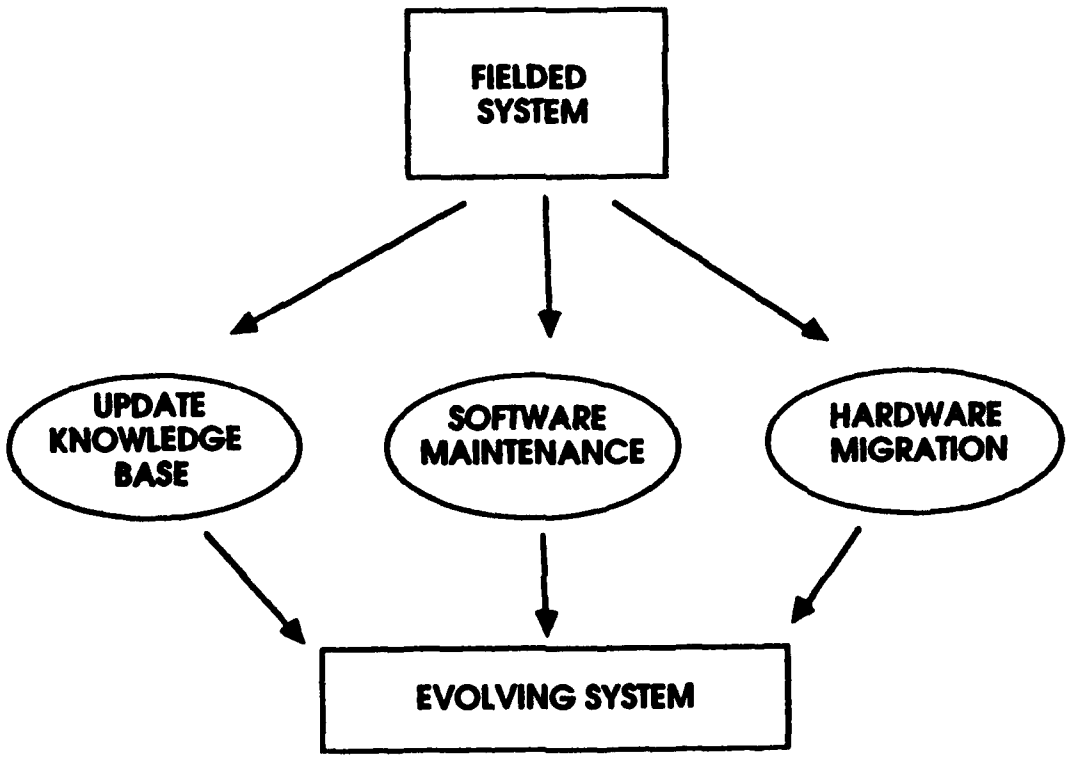
SYSTEM MAINTENANCE

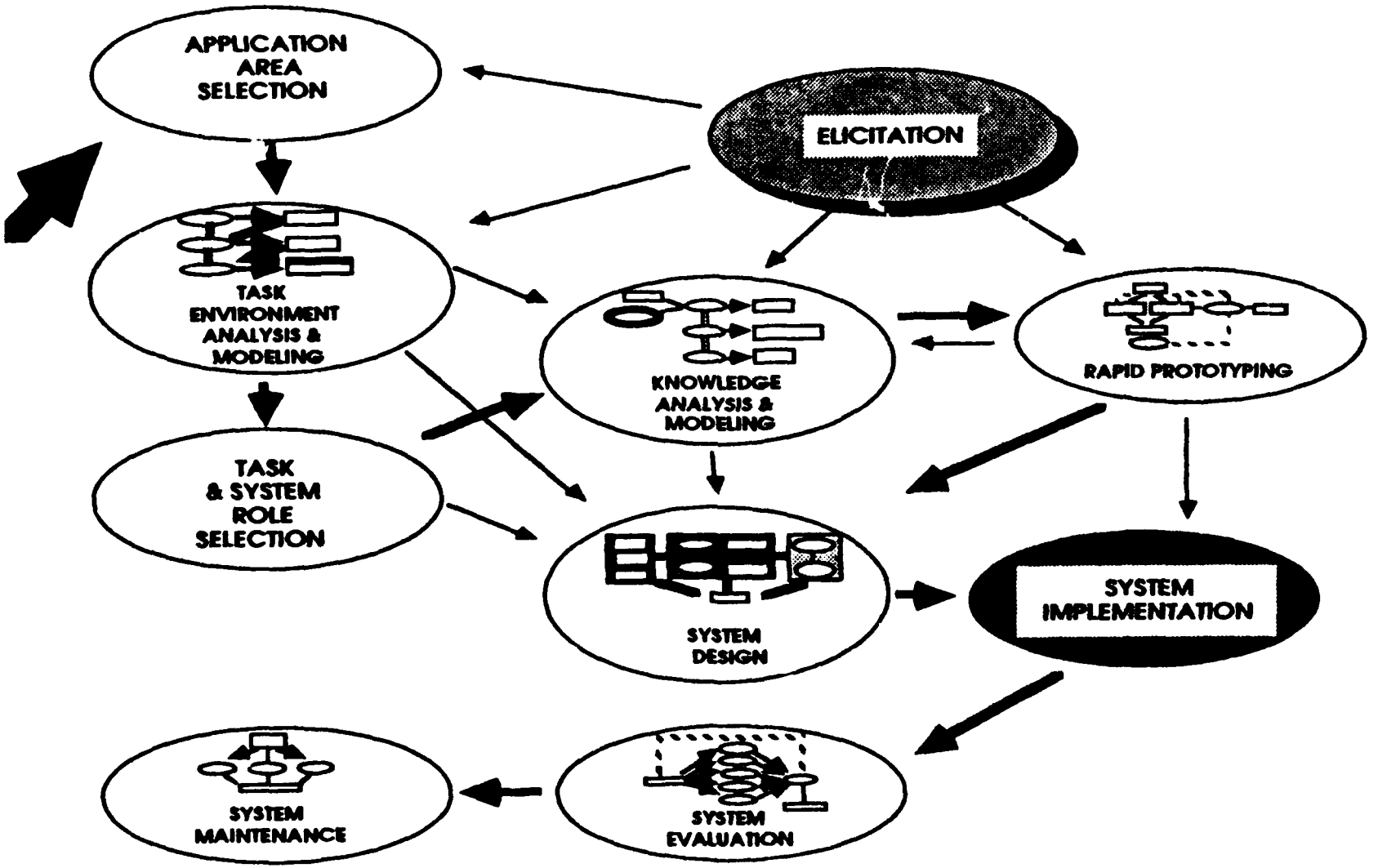


Modify the Methodology when:

- **Knowledge is widely distibuted throughout the organization**
- **A detailed task environment model is not feasible**
- **Time and budget are constrained**
- **An embedded system is required**
- **Use the methodology as a grab-bag of tools and techniques**

APPLICATION SELECTION

DETAILED METHODOLOGY



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MOTIVATION TO BUILD EXPERT SYSTEMS

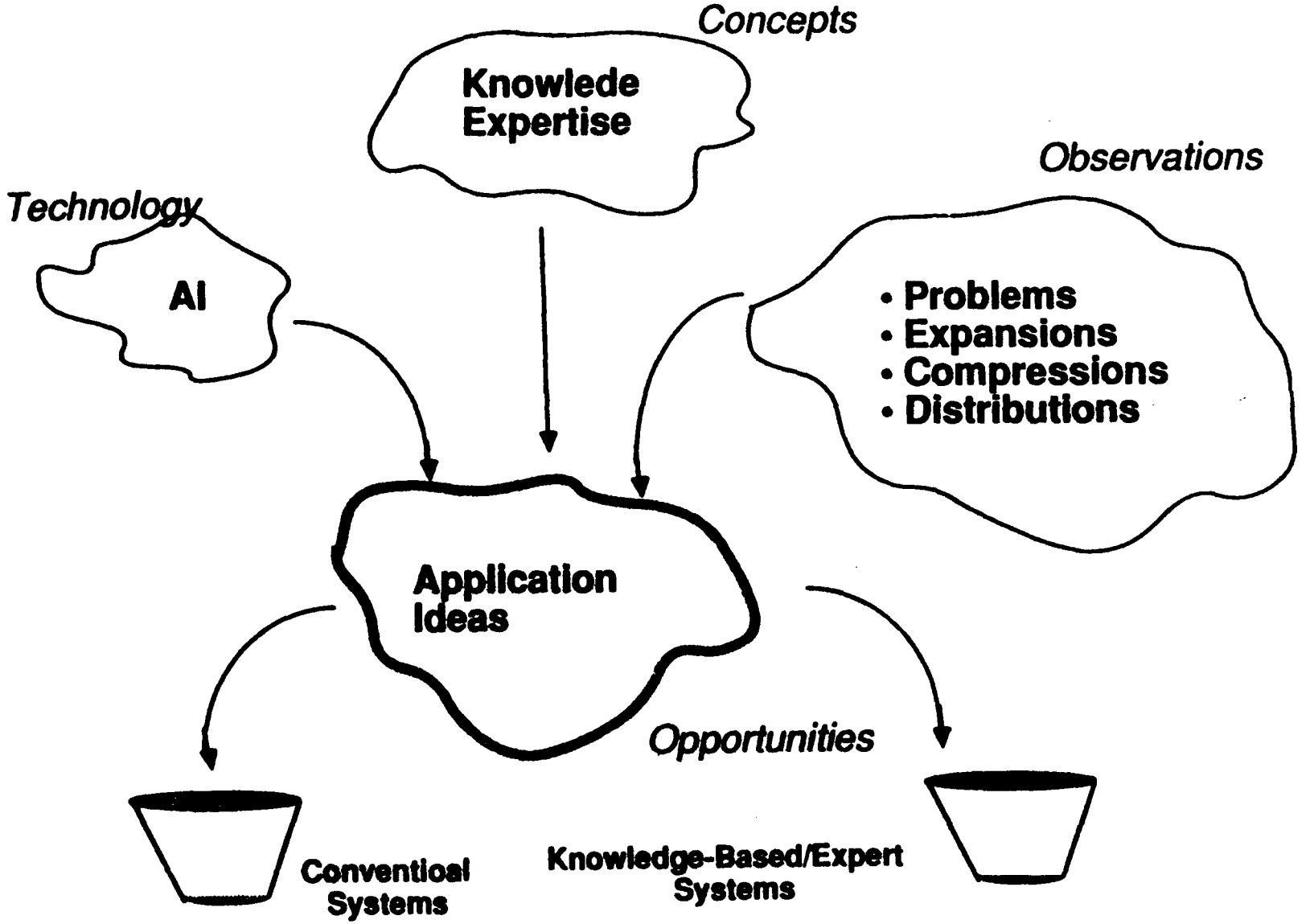
KNOWLEDGE

- **Leverage Expertise**
  - **Capturing**
  - **Structuring**
  - **Preserving**
  - **Enhancing**
  - **Distributing**

BUSINESS

- **Extend Benefit Streams**
- **Create Competitive Advantages**
- **Leverage Opportunities**
- **Reduce Risks**

APPLICATION SELECTION



PROBLEMS IN PERFORMING KNOWLEDGE-INTENSIVE TASKS

Human Memory:
- **overwhelmed**
- **forgetting**
- **distortions**
- **blind sports**
- **dead ends**

Intelligence:
- **weak in ancillary areas**
- **need for various types of intelligences**

Social Division of Labor
- **labor/knowledge mismatch**
- **temporal discontinuities**
- **"seeing through other worlds"**

EXPANSIONS OF KNOWLEDGE-INTENSIVE TASKS

TASK WORLD

- **Expert performers must know more**
- **More expert performers needed**

TASK KNOWLEDGE

- **New principles must be incorporated**
- **Integrate changing principles with existing ones**

COMPRESSIONS OF KNOWLEDGE-INTENSIVE TASKS

- **Do more tasks performances/time unit**
- **Cover more of a task performance/time unit**
- **Consider more possibilities, options, outcomes/time unit**
- **Cover more highly selective subtleties/time unit**

DISTRIBUTIONS OF KNOWLEDGE-INTENSIVE TASKS

- **Move Expertise to Novices**
- **Move Expertise to**
  - **Automated Processes**
  - **Physical Prepations**
  - **Field Operations**
  - **Customers**
- **Add Expertise to Information**

CANDIDATE FOR
A FIRST EXPERT SYSTEM APPLICATION

- **It matters**
- **A valuable asset exists**
- **It can be exploited**
- **It can be done**
- **It can't be done in other ways**

KNOWLEDGE MANAGEMENT

- **Identify the *Critical Knowledge Factors* of the Organization**
- **Identify Opportunities for *Leveraging Knowledge* within the Organization**
- **Develop a Perspective of the *Value of Knowledge* for the Organization**
- **Identify the Necessary R&D activities**

APPLICATION SELECTION CRITERIA

- **Business Opportunities**
- **Nature of the Expertise**
- **Characteristics of the User Organization**
- **Technical/Development Issues**
- **Cost/Benefit Analyses**

BUSINESS OPPORTUNITIES

- **What are the *Current* and *Future* Missions of the Organization?**
- **What is the Value of this Task to *Present* Operations?**
- **What is the Value of this Task to *Future* Operations?**
- **What are the Current Bottlenecks and Pressure Points?**
- **What are the Potential Benefit *Streams*?**
- **What *Operational Changes* will be Required to make this system effective?**

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NATURE OF THE EXPERTISE

- **Do Human Experts Exist?**
  - **one, several?**
- **Is Expert Performance Clearly Better?**
- **Is the Task Based on Judgement?**
- **Does the task require only narrowly specialized knowledge?**
- **What "types of intelligence" are required to be successful (e.g. linguistic, logical, spatial, etc.)?**
- **Is there Adequate Access to Experts?**
- **What Documentation and Training Exist?**

CHARACTERISTICS OF THE USER ORGANIZATION

- **Is the Application Area a Concern to the User Community?**
- **Are the Users Interested in Supporting a KBS?**
- **Is there Support (approval vs. budget) from User Management?**
- **To what Degree will this System Change the User Operation?**

TECHNICAL/DEVELOPMENT ISSUES

- **Does the System Require the Use of AI Technology?**
- **Is the System Implementable with Available Tools?**
  - **development**
  - **delivery**
- **What are the Systems Integration Requirements?**
- **What Technical Resources are Available?**
  - **personnel**
  - **tools**

COST/BENEFIT ANALYSIS

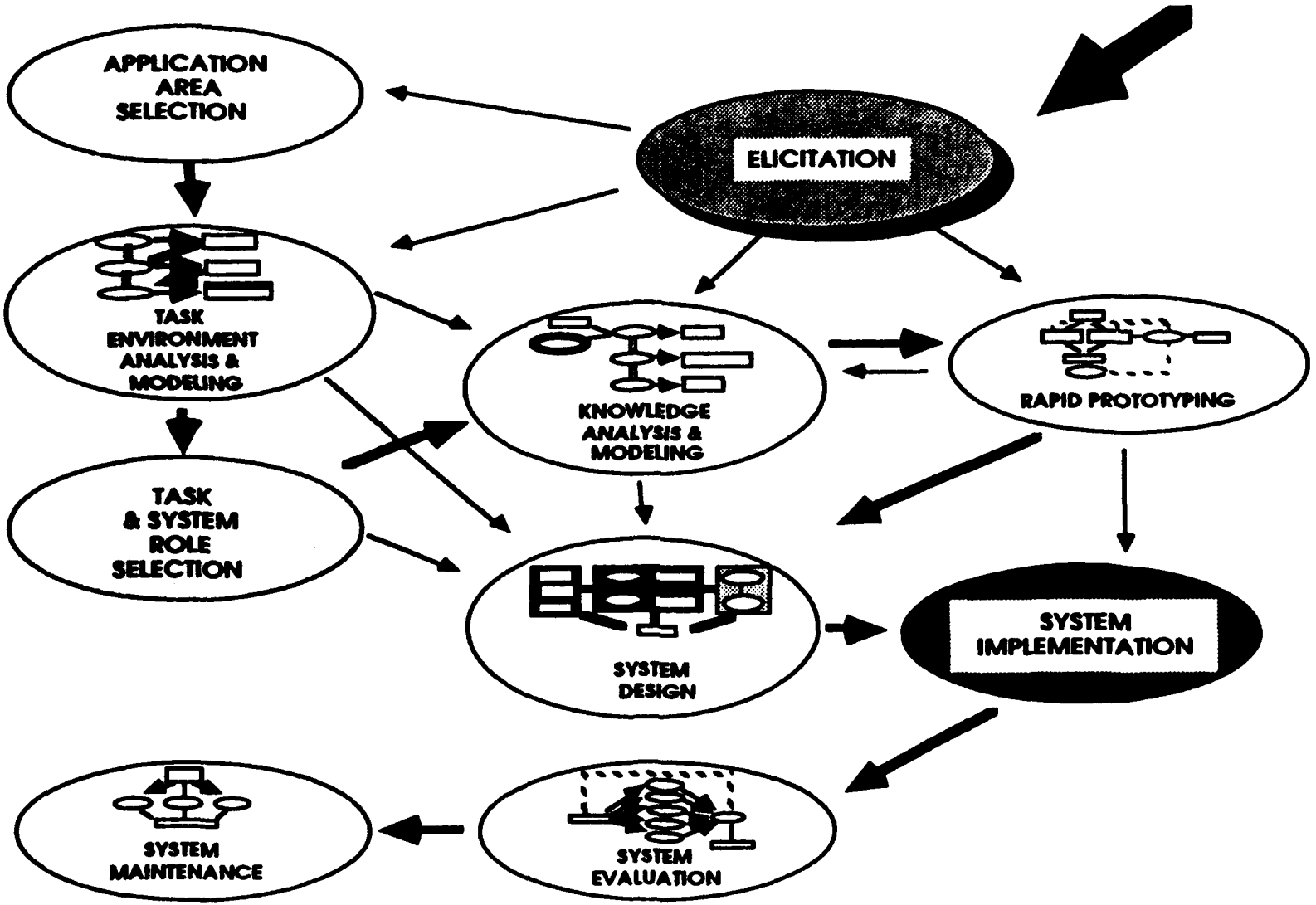
- **Is there a high pay-off?**
- **What is the ratio of expected value vs. costs?**
  - **"standard" benefits**
  - **other "benefit streams"**
- **What is the Internal Return on Investment?**
- **How Long is the Expected Pay-Back Period?**
- **How Variable are the Projected Costs, Timing, and Budgets?**

APPROACHES TO APPLICATION SELECTION

- **Senior Management Designates Application**
- **Senior Management Brainstorming Workshops**
- **Identification by Technical Group; Selection by Management**
- **Identification and Selection by Technical Group through Systematic Management Interviews**
- **End User Computing**

KNOWLEDGE ELICITATION

DETAILED METHODOLOGY



WHY "ELICITATION?"

- **"Acquisition" suggests a conquering role (emphasis on the acquirer)**
- **"Extraction" suggests dentistry (pain) or mining (forcible removal of a non-renewable resource)**
- **"Elicitation" suggests a collaborative role (emphasis on the process, and the delicacy required to preserve the integrity of the knowledge sought.**

TWO APPROACHES TO KNOWLEDGE PROFILING

	(Classic) Systems Development	(New) Knowledge Engineering
SCOPE	Exclusiveness: Consider only what the computer can do	Richness: Grasp all that's going on prior to selection of parts to be worked on
MENTAL SET	Preconception: If-then logic will prevail	Preconception: Some kind of valid rationale will eventually become clear
ROLE	System spec: Developer imagines how he would solve the problem	System spec: Really has to be worked into by the expert, user and developer

DESCRIPTION OF THE PROCESS OF KNOWLEDGE ELICITATION

Between the Knowledge Elicitation Team and the Experts

- **Four parallel interactive, evolutionary processes**
  - **Mutual trust building**
  - **Cognitive calibration**
  - **Getting to presuppositions**
  - **Verified informational transfer**

MUTUAL TRUST BUILDING

- **Identify Common References / Experiences**
- **Test Reliability and Integrity**
- **Share Private Values and Opinions**
- **Sharing Vulnerabilities**

COGNITIVE CALIBRATION

- **Identify Type of Knowledge Holders**
- **Discover & Overcome Obvious Systematic Differences**
- **Eliciter Adapts to the Expert**
- **Expert Becomes More Aware of What to Express to Eliciter**

GETTING TO PRESUPPOSITIONS

- **Why does the Expert Think He's Here?**
- **Notice Assumptions / Implications**

VERIFIED INFORMATION TRANSFER

- **Information Independently Known to be True**
- **Probing and Feedback**
- **Consistency Tests**

DESCRIPTION OF THE PROCESS OF KNOWLEDGE ELICITATION

Internal to the Knowledge Elicitation Team

- **Recursive process**
  - **Landmarking**
  - **Comparing to what**
  - **Establishing patterns**
  - **Mapping and detailing**

LANDMARKING

- "Surviving the Unknown"
- Identifying:
  - The "Obvious"
  - "Mirages"
  - "Swamps & Quicksand"
- Creating a Vocabularly for the Team

COMPARING TO WHAT

- **"Objectifying Subjective Experience"**

- **Compare to:**
  - **Other Expertise**
  - **Other Experts**
  - **Me and You**
  - **Models**
  - **Theories**

ESTABLISHING PATTERNS

- **"Attributing Order"**
- **Look for Patterns**
  - **Logic**
  - **Analogy**
  - **Taxonomy**
  - **Organizing Principles**
  - **Rules**

MAPPING AND DETAILING

- **"Describing Reality"**

- **Identify**
  - **Fundamentals**
  - **Consequences**
  - **Links**
  - **Descriptors**
  - **Closure/Completeness Criteria**

WHAT TO DO AFTER CHOOSING THE EXPERTISE TYPE THAT FITS A KNOWLEDGE HOLDER

- **Test whether attribution is accurate**
- **Achieve matching communication mode**
- **Revise hypotheses about the functionality of the anticipated system accordingly**
- **Use corresponding structure to determine elicitation techniques**

TEST WHETHER ATTRIBUTION IS ACCURATE

- **What kind of result does the knowledge holding expert seek?**

- Professional Practioner:	The right answer
- Practical Knowledge Worker:	The practical solution
- Performer:	Victorious dominance (perfect performance)
- Communicating Negotiator:	The best we can

TEST WHETHER ATTRIBUTION IS ACCURATE (Continued)

What kind of training does the expert have?

PP: Formal training that features logical conceptual structure: Academic emphasis (Degrees and certifications may be important)

PKW: Apprenticeship, or other "guided" experience (experience at progressively more sohpisticated levels of activity may be important)

PERF: Discipleship to a master

CN: Tend to be "naturals" (Experimental/ideological training)

ACHIEVE MATCHING COMMUNICATIONS MODE

- Seeking *truth* and conforming with scientific standards is the fundamental issue for the *professional practitioner*
- The *practical knowledge worker* takes particular pride in *efficiency* and/or coping with volume-induced pressure
- The *practical knowledge worker* tends to believe that the *information (s)he needs is random*, casual or free floating
- *Performers* value the esthetic, but primarily as it relates to their own performances (*ego-centered*)
- To the *communicator-negotiator*, being professionally competent involves *keeping his "client" "under control"*

REVISE HYPOTHESES ABOUT THE FUNCTIONALITY OF THE ANTICIPATED SYSTEM ACCORDINGLY

- A prototype system for a *professional practitioner* may often take the form of a *typical example*., with further development following similar examples or other logically related steps

- A prototype system for a *practical knowledge worker* will be a few "*strategic" sequences* within their task - may be inherent to core expertise or only supportive of it

- *Performer's* prototypes are for *support* purposes only

- Most prototypes for *communicating negotiators* will be *support* only, an extended system will probably come from knowledge worker or professional practitioner aspects of communicating negotiator work

USE CORRESPONDING STRUCTURE TO GUIDE ELICITATION

- E.G.: Expect *practical knowledge workers* to be interested and convinced there's "structure" behind their work only after the elicitors have demonstrated that structure

- E.G.: Expect *communicating negotiators* to be bewildered about the results expected from the process for an unbearably long time

- E.G.: Expect *scientifically trained experts who are acting as practical knowledge workers* to pick up every cue that suggests they "should" be functioning like professional practitioners

- E.G.: Expect *experienced system developers* to be strongly under the influence of the *professional practioner* model

- E.G.: Expect *performers* to turn their interaction with you into a performance

KNOWLEDGE ELICITATION TECHNIQUES

- **Direct Methods**
- **Indirect Methods**

KNOWLEDGE ELICITATION TECHNIQUES

DIRECT METHODS

- **Interviews**
  - **structured vs. unstructured**
  - **individual vs. group**
- **Observation**
- **Simulation**
- **Interactive Prototyping**
- **Protocol Analysis**
- **Questionnaires**
- **Closed Curves**
- **Inferential Flows**

KNOWLEDGE ELICITATION TECHNIQUES

INDIRECT METHODS

- **Machine Induction**
- **Extraction From Codified Sources**
- **Multi-Dimensional Scaling**
- **Conceptual Sorting**
- **General Weighted Networks**
- **Ordered Trees**
- **Repertory Grid Analysis**
- **Hierarchies**

INTERVIEWS

DESCRIPTION: Experts give informal or prepared tutorial on the task domain and functions; various formats but generally directed by knowledge elicitor

ADVANTAGES:
- Access to Public/Shared Knowledge
- Easy to Use
- Lots of Information Gained Quickly

DISADVANTAGES:
- Relies on Recall from Long Term Memory
- Time Consuming
- Expensive

BEST USE:
- Task Environment Elicitation
- Initial Knowledge Elicitation
- all types of Knowledge Holders

INTERVIEWS

- **Structured vs. Unstructured**
- **Group vs. Individual**
- **Competence vs. Performance**

COMPETENCE INTERVIEWS

Retrospective Reports which Document:

- **the structure of the task environment**
- **the structure of the task**
- **the structure of the task knowledge**

Consisting of:

- **descriptions of the task environment**
- **descriptions of the mental artifacts of the task knowledge**
- **recalls of habitual procedures**
- **recalls of most-used strategies**
- **self reflection (meta-comments)**

Require

No Special Set Up

PERFORMANCE INTERVIEWS

Concurrent Reports which Document:

Real-Time sequences of knowledge and reasoning states

Consisting of:

- **descriptions of the task environment**
- **descriptions of task operators**
- **descriptions of task goals**
- **a dump of short term memory**
- **very few meta-comments**

Require

The Natural Task Environment

PROTOCOL ANALYSIS

DESCRIPTION:	**Expert gives verbal account of what he/she is doing/thinkg about during a task performance**
ADVANTAGES:	**Permits Inference of "Private Knowledge" Good way to get Details of Specific Mental Actions**
DISADVANTAGES:	**Can interfere with Task Performance Difficult for Some Experts to Verbalize Analysis is Laborious**
BEST USE:	**Second Round Knowledge Elicitation**

HOW TO CONDUCT AN INTERVIEW

- **Preparation**
  - **Identify the goals of the interview**
  - **Determine the type of interview**
  - **Do background work and prepare accordingly**
- **Roles**
  - **lead interviewer**
  - **support interviewer**
  - **recorder (notes, audio and video tapes)**
- **Timing**
  - **between elicitation team**
  - **with experts**

GENERAL GUIDELINES

- **Allow Expert to Talk**
- **Try to Avoid Interruptions**
- **Try to Avoid Imposing Your Own Interpretation**
- **Use the Experts' Language if Possible**

SIMULATION

DESCRIPTION:	**Creation of an environment to induce a performance; various formats**
ADVANTAGES:	**Ability to get Performance Knowledge without Impacting Operations**
DISADVANTAGES:	**Can be Contrived** **Can be Impractical and Expensive**
BEST USE:	**Knowledge Elicitation in Sensitive Environments**

SIMULATION

- **Task Environment**
- **Envisioned Expert System**
- **Expert/Novice**
  - **Experts' hands, eyes, etc.**

SIMULATION OF THE TASK ENVIRONMENT

Artificially Elicited Comments which Document:

Sequences of knowledge and reasoning states

Consisting of

- **descriptions of the task materials**
- **descriptions of task operators**
- **descriptions of task goals**
- **meta-comments**

Require

A Collection of Task Materials

A Set-Up of the Task Environment

SIMULATION OF THE ENVISIONED SYSTEM

Artificially Elicited Comments which Document:

Required interactions between system and user

Consisting of

- **requests for information**
- **formt of anticipated advice**
- **intuititive navigation through system**

Require

A Collection of Task Materials

Staging to simulate expert system/user

SIMULATION OF EXPERT'S EYES, HANDS, ETC.

Artificially Elicited Comments which Document:

Information heeded during task performance

The interaction between information and knowledge

Consisting of

- **requests for information**
- **active verbal protocols**

Require

A Collection of Task Materials

Selective limitation of

- **avenues of communication**
- **accessibility of information**

OBSERVATION

DESCRIPTION: Oberserving and recording the expert during an uninterrupted performance of the task; generally directed by the expert

ADVANTAGES:
- Develop Common Understanding of the Task Environment
- Identify User/Expert Roles

DISADVANTAGES:
- Can be Highly Sensitive
- Possibility of Interrupting Operations
- Heavy Burden on Elicitor

BEST USE:
- Follow Up Task Environment Elicitation
- Necessary in "Real-Time" Operational Settings

INTERACTIVE PROTOTYPING

DESCRIPTION:	**Working with the expert and a prototyping tool to determine the content and structure of the knowledge**
ADVANTAGES:	**Ability to Get the Experts' Structure Possible to Use as a Start for Rapid and/or System Protoyping**
DISADVANTAGES:	**Tools Dictate Available Structure Can Intimidate some Experts**
BEST USE:	**Second Round Knowledge Elicitation with Computer Literate Experts**

EXTRACTION FROM CODIFIED SOURCES

DESCRIPTION:	**Use previously codified sources (textbooks, manuals, etc.) to derive rules**
ADVANTAGES:	**Quick and Inexpensive**
DISADVANTAGES:	**Only Allows Access to "Public Facts" Often Leads to Systems which Do Not Address the Cognitive Aspects of the Task**
BEST USE:	**For an Initial Demo to Gain Corporate Commitment to a Project**

MACHINE INDUCTION

DESCRIPTION:	**Use inductive tool to generate rules from examples**
ADVANTAGES:	**Only Needs Examples, therefore Limits the Knowledge Modeling Effort**
DISADVANTAGES:	**Does not Address Cognitive Aspects Rules Have Little Resemblance to those Elicited From Human Experts**
BEST USE:	**To develop rules in knowledge domains that are poorly understood**

POSSIBLE ELICITATION TECHNIQUES FOR DIFFERENT TYPES OF KNOWLEDGE

Types of Knowledge	Interviews	Observation	Simulation	Protocol Analysis	Interactive Prototyping	Extraction from Codified Sources	Machine-Induction
FACTS	X		X		X	X	
HEURISTICS			X	X	X		X
CONCEPTS/ RELATIONSHIPS	X				X		
CLASSIFICATIONS					X		X
META-KNOWLEDGE				X			
PROBLEM NEGOTIATION		X	X				
USER CHARACTERISTICS	X	X	X				
PROCEDURAL KNOWLEDGE		X	X				
TACIT KNOWLEDGE				X			X

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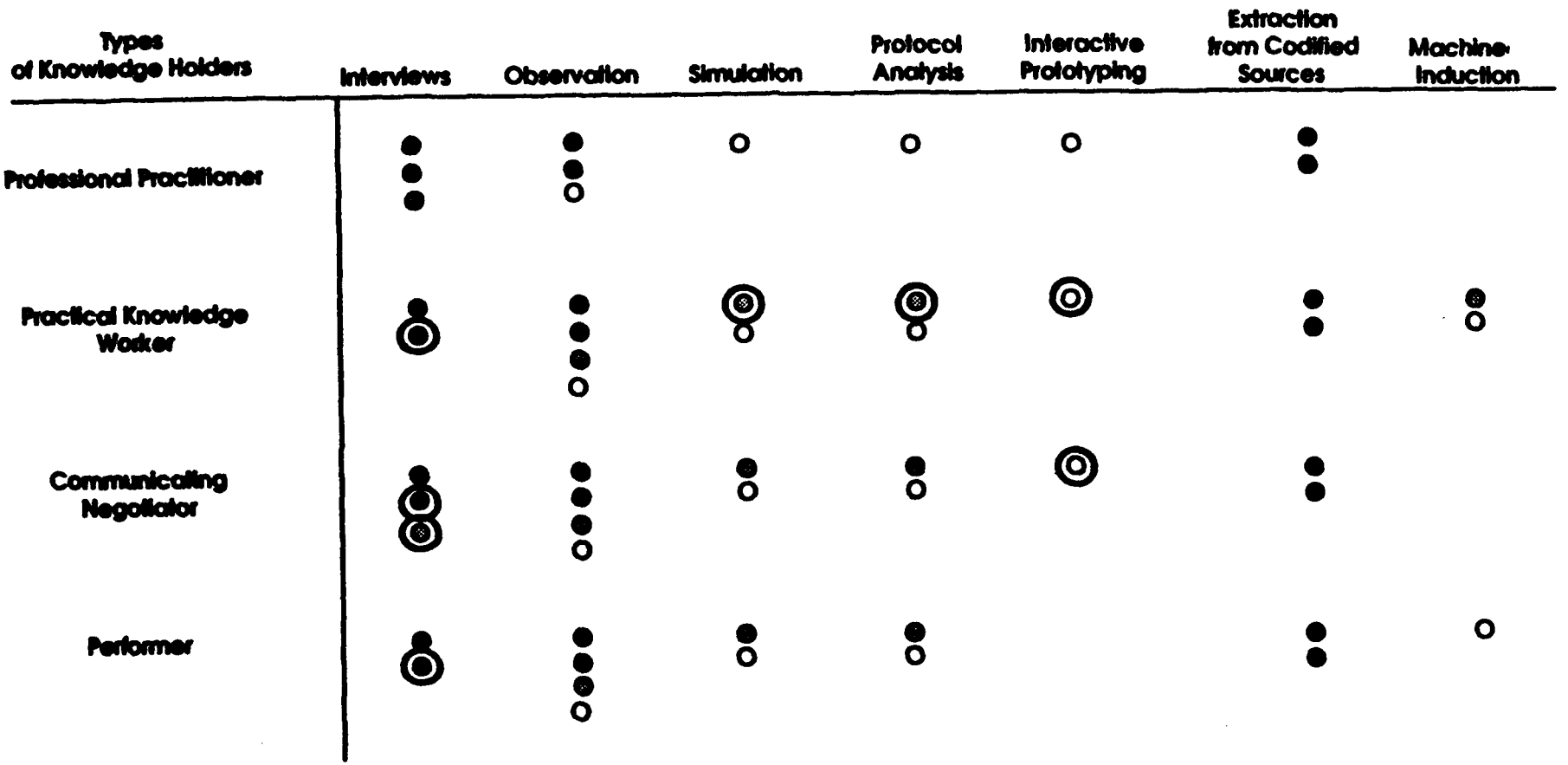
POSSIBLE ELICITATION TECHNIQUES FOR DIFFERENT TYPES OF KNOWLEDGE HOLDERS



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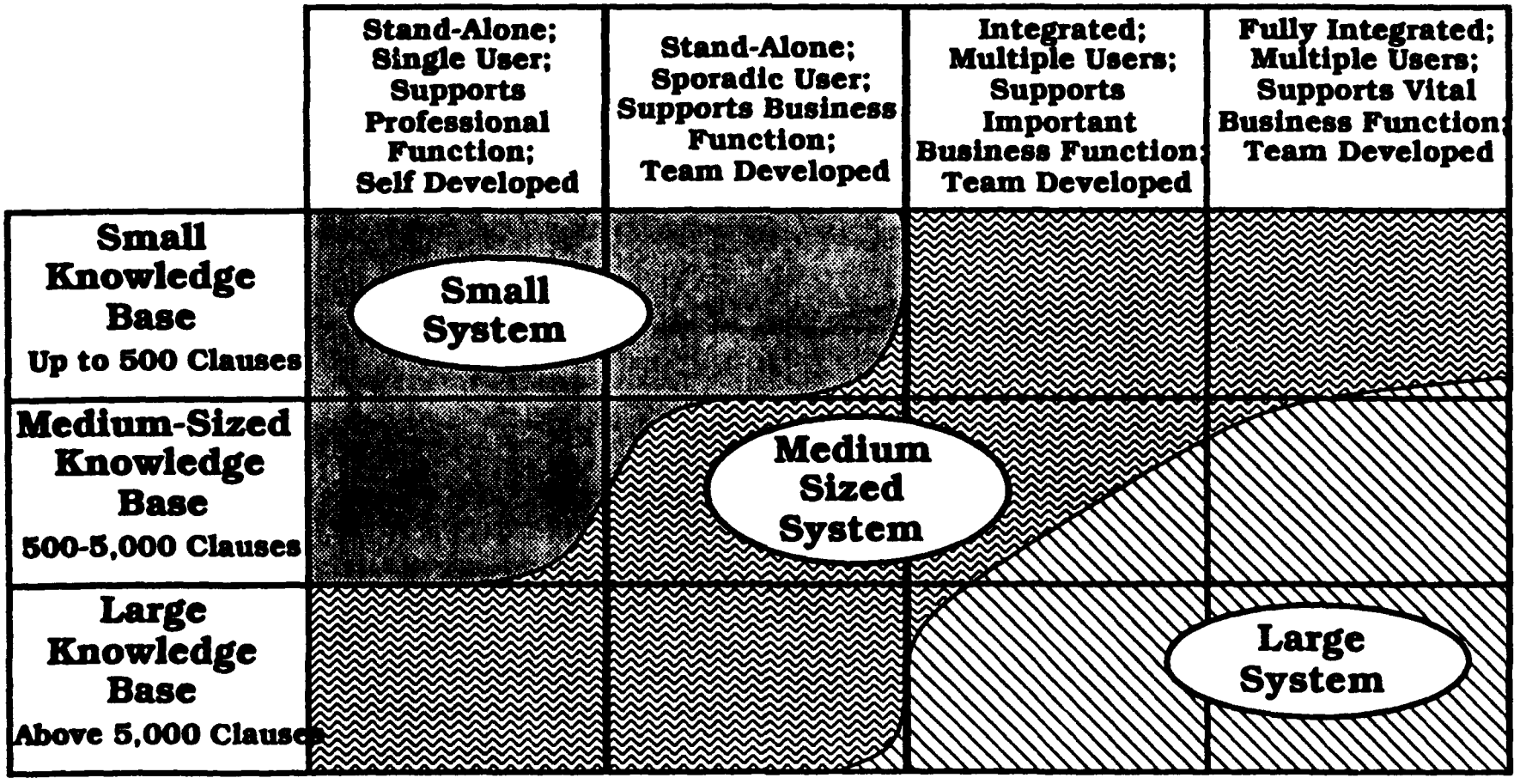
PROJECT MANAGEMENT AND ROLES OF THE PROJECT TEAM

TYPES OF PROJECTS



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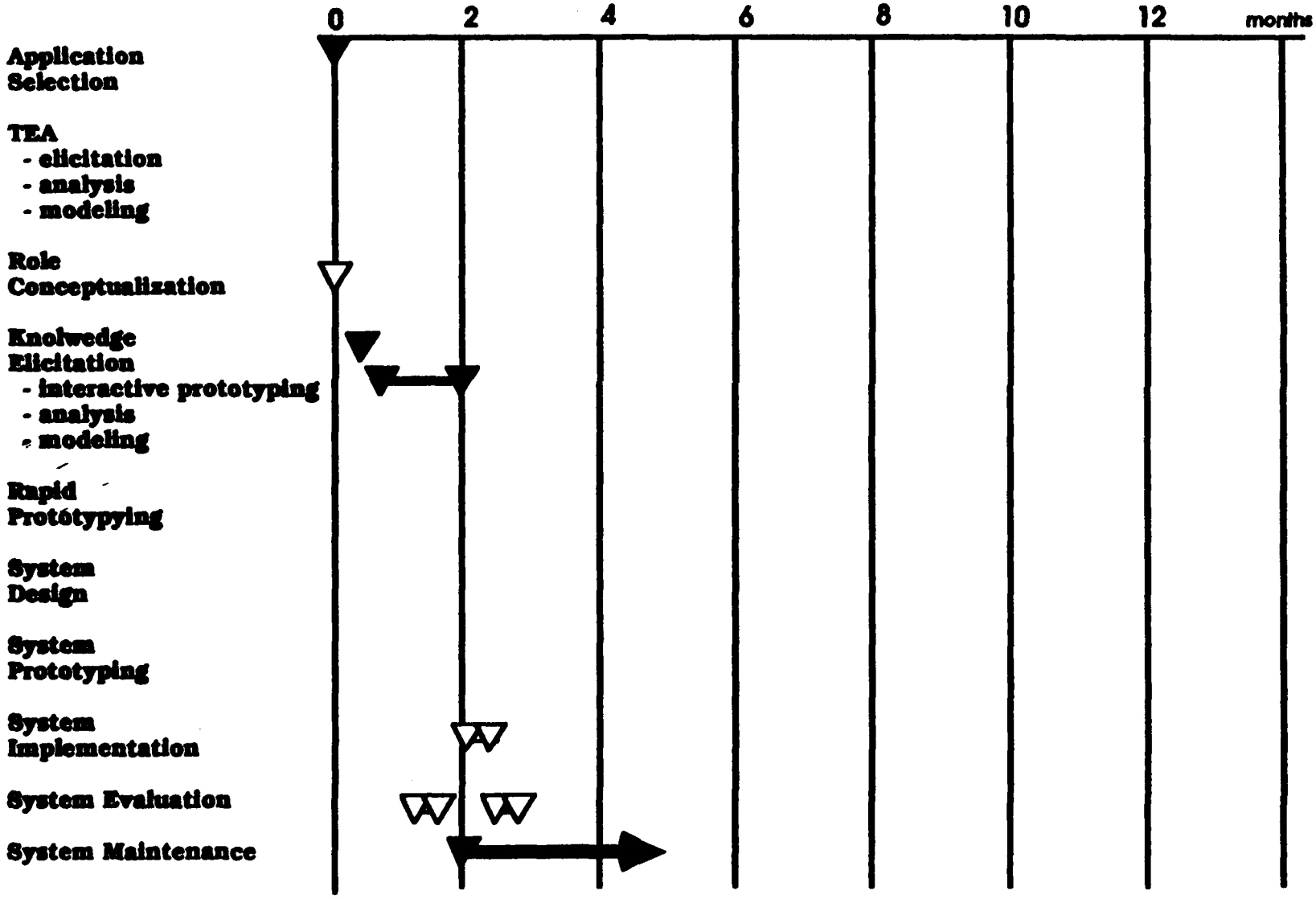
SMALL SYSTEMS



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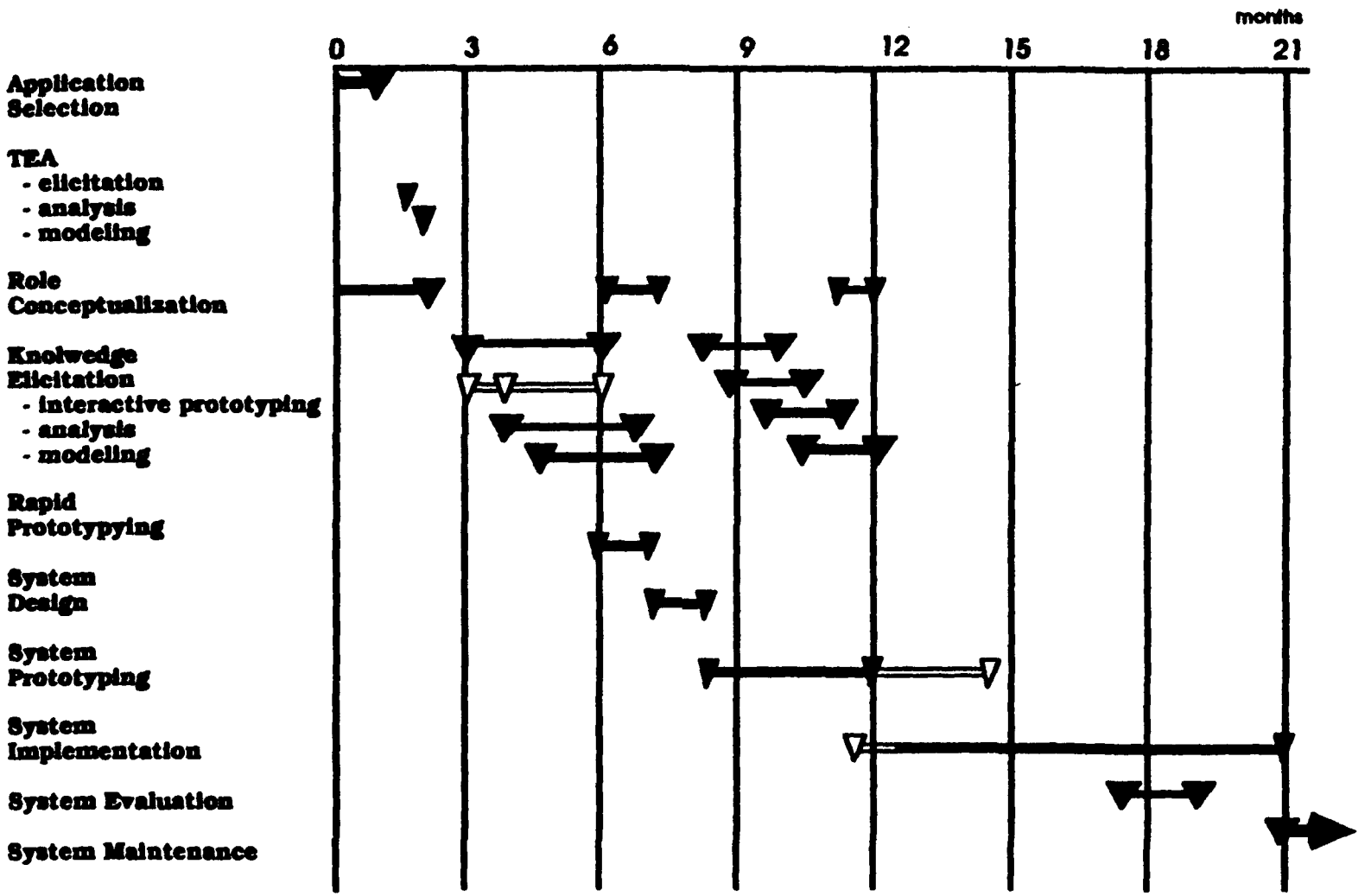
MEDIUM-SIZED SYSTEMS



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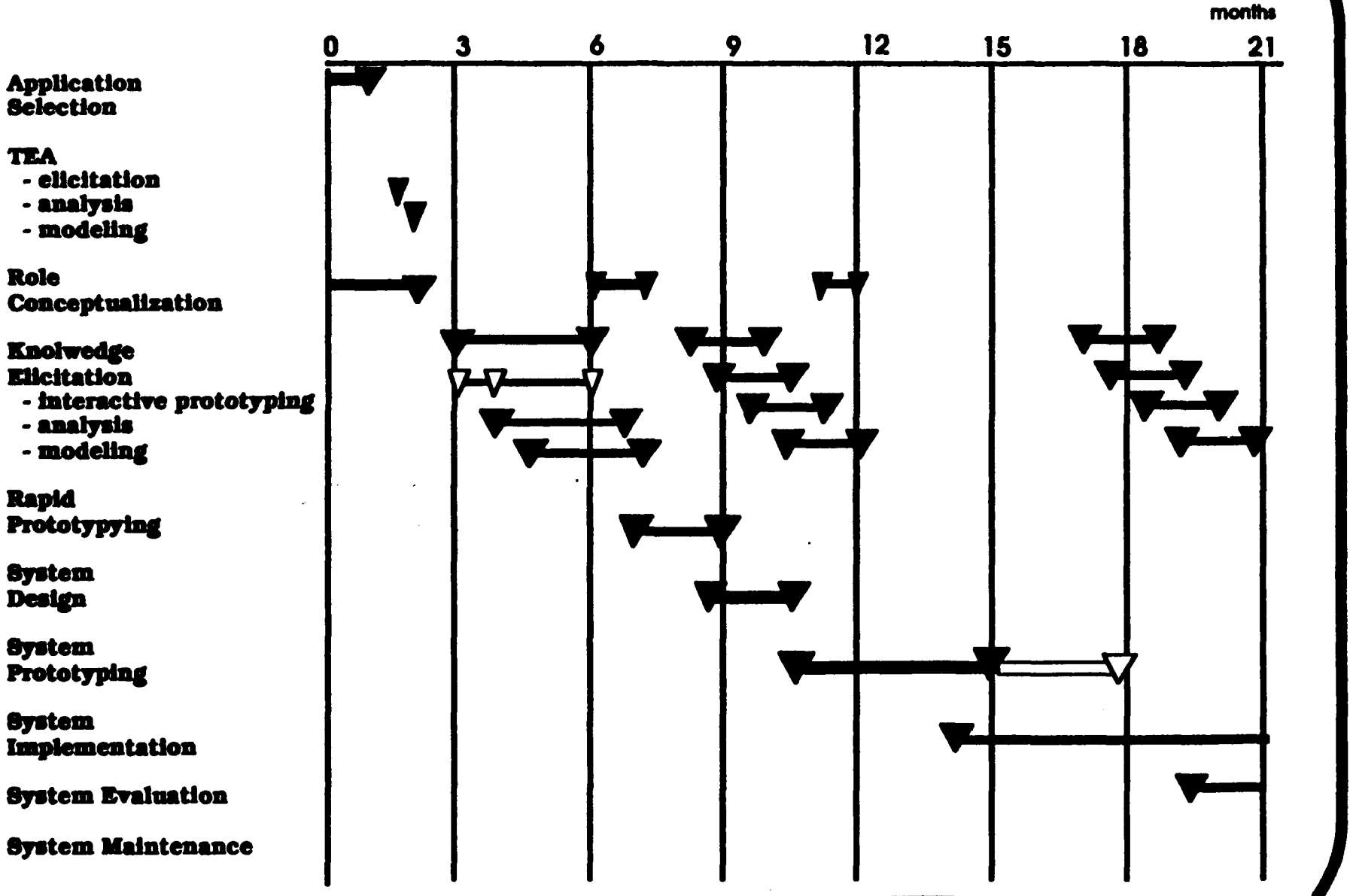
LARGE SYSTEMS



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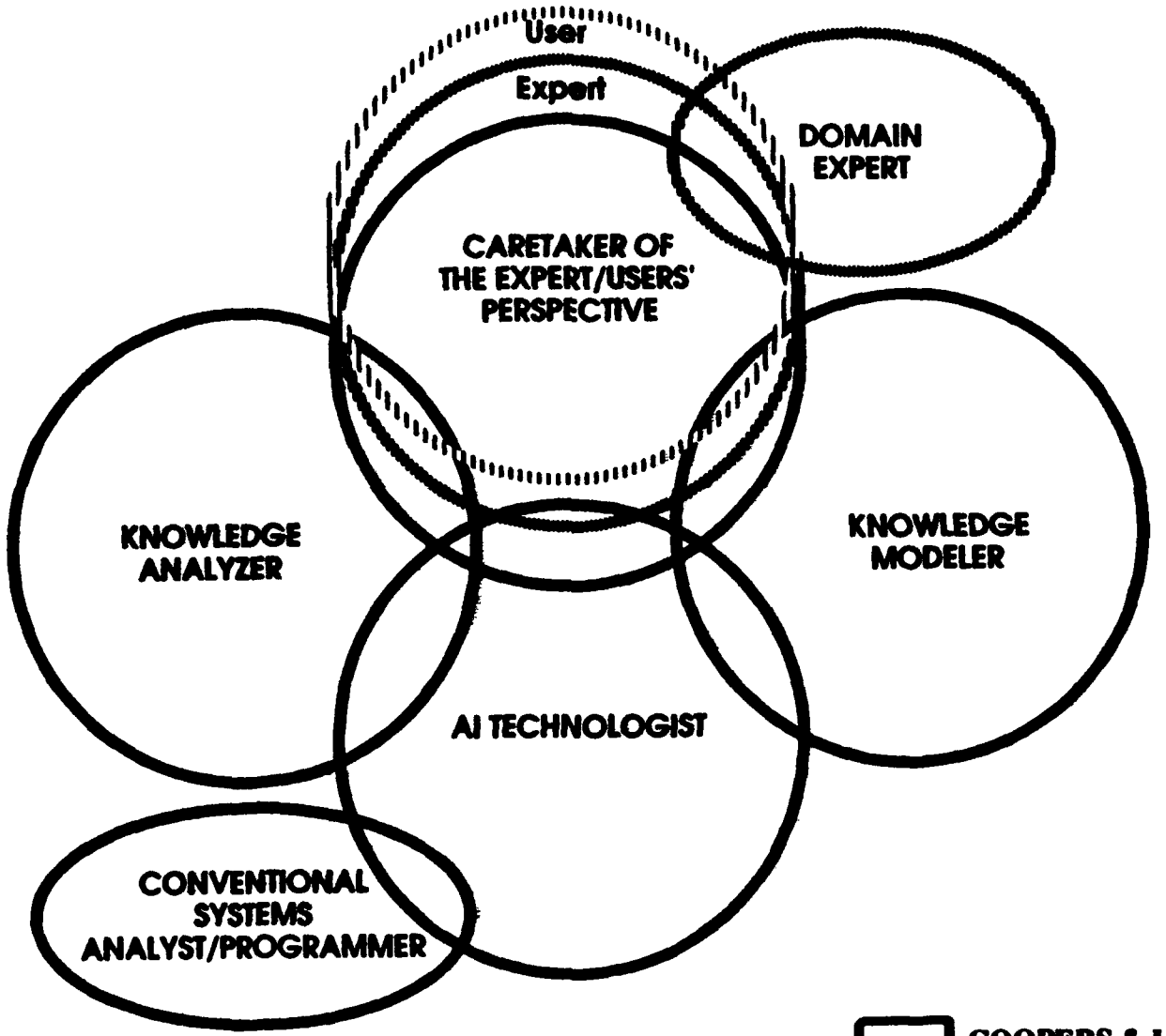
TEAM ROLES



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CARETAKER OF THE EXPERT/USER PERSPECTIVE

KNOWS HOW TO FIND OUT
- WHAT AN EXPERT KNOWS AND
- WHAT THE USERS WANT

SKILLS

- **Relationship skills**
- **Interviewing skills**
- **Assertiveness skills**
- **Verbal/conceptual skills**
- **Enthusiasm for subject matter**
- **Applications sense**

KNOWLEDGE ANALYZER

KNOWS HOW TO IDENTIFY THE ELEMENTS, THE KEY RELATIONSHIPS AND THE PRINCIPLES WHICH MAKE UP A BODY OF EXPERTISE

SKILLS

- **Linguistic Skills**
- **"Psycho-Analysis"**
- **Sociological skills**
- **Communication skills**

KNOWLEDGE MODELER

KNOWS HOW TO MAKE SENSE OF WHAT AN EXPERT KNOWS

SKILLS

- **Technical philosophy (especially logic)**
- **Conceptual synthesizer**
- **Cognitive psychology**

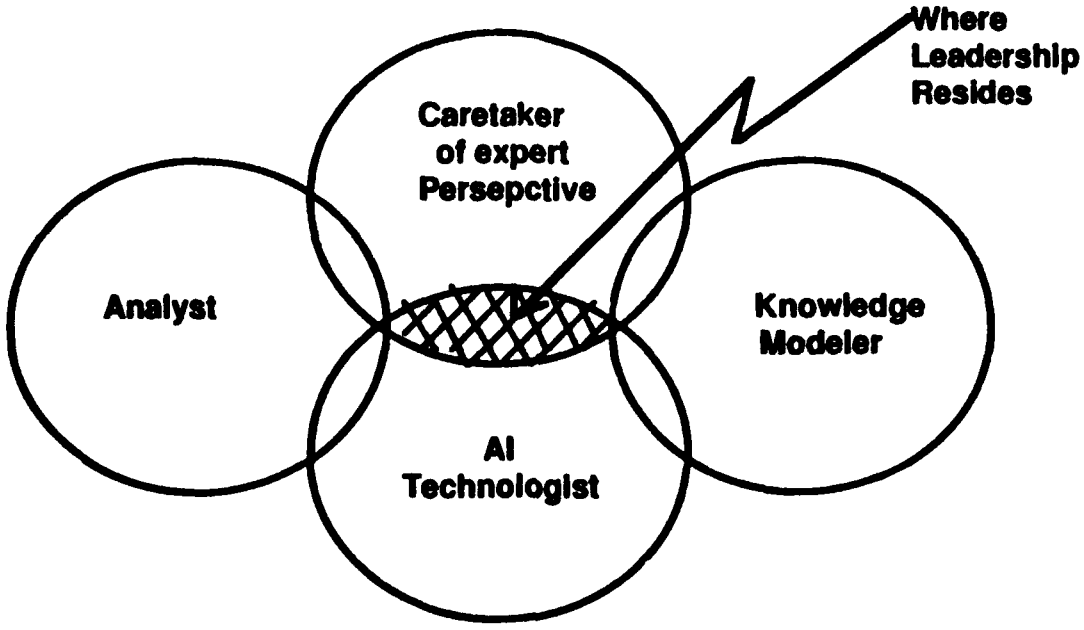
AI TECHNOLOGIST

KNOWS WHAT PROBLEMS CAN BE HANDLED BY AI SYSTEMS AND HOW TO REDUCE THEM INTO A SYSTEM ARCHITECURE AND COMPUTER SOFTWARE

SKILLS

- **AI architecture**
- **Expert system experience**
- **Applications sense**

Who "Leads" the Interviews?



- Must have a "clear" idea of what knowledge the group is after
- Must have a good vision of possible functionality of the demo system
- Should have some clarity about the ultimate functionality of the system
- "Take the lead" means be the primary questioner

ROLES IN KNOWLEDGE ELICITATION

- **Subject matter experts**
  - **The expert -- the knowledge holder**
  - **Domain experts**
  - **Users**

- **Knowledge elicitors**
  - **Caretaker of the experts/user's perspective**
  - **Knowledge analyzer**
  - **Rational reconstructor**

- **AI technologists**
  - **System architect**
  - **Programmer**

DIFFERENT PERSPECTIVES REQUIRED ON THE TEAM

- **Cognitive Scientist's Perspective**
- **Psychologist's Perspective**
- **Ethnographer's Perspective**
- **System Analyst/Designer's Perspective**
- **Consultant's Perspective**

THE COGNITIVE SCIENTIST'S PERSPECTIVE

- **Bring knowledge of how the human brain processes information and solves problems**

- **Understands the "meaning" of speech**
  - **vocabulary and temporal structuring utterances**
  - **degrees of completeness of utterances**
  - **speech bursts, speech acts, relation of speech acts to memory**

THE PSYCHOLOGIST'S PERSPECTIVE

- **Bring self awareness**

- **Understands how to foster communication**
  - **must reduce, not add to intimidating aspects of the situation**
  - **must recognize that some of his own values and attitudes will bar his understanding**
  - **must reveal himself sufficiently to gain trust**

THE ETHNOGRAPHER'S PERSPECTIVE

- **Bring self-awareness and naivete**

- **Understands the "culture" of the expert**
  - **purpose is to learn; not to judge**
  - **efficient, effective transfer of understanding**
  - **transfer is wanted, not translation**
  - **do not neglect artifacts, rituals and day-by-day routines**

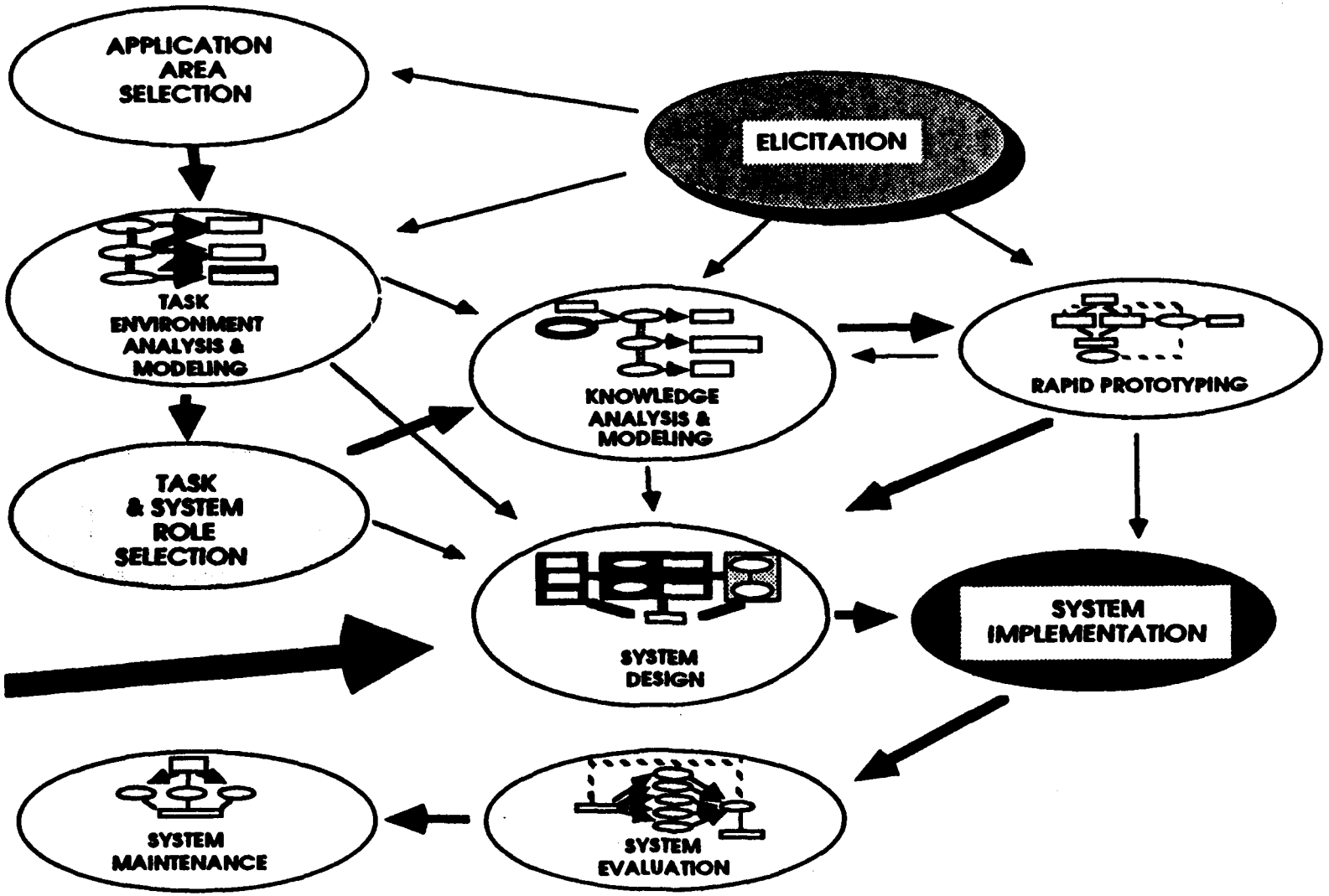
THE SYSTEM ANALYST/DESIGNER'S PERSPECTIVE

- **Bring knowledge of computer capabilities and system development techniques**

- **Understands the "capabilities" of a system**
  - **Tests the applicability of system concepts**
  - **Translates from "native" language into systems language**
  - **Emphasizes the "product"**
  - **Takes advantage of computer technologies**

SYSTEM DESIGN

DETAILED METHODOLOGY



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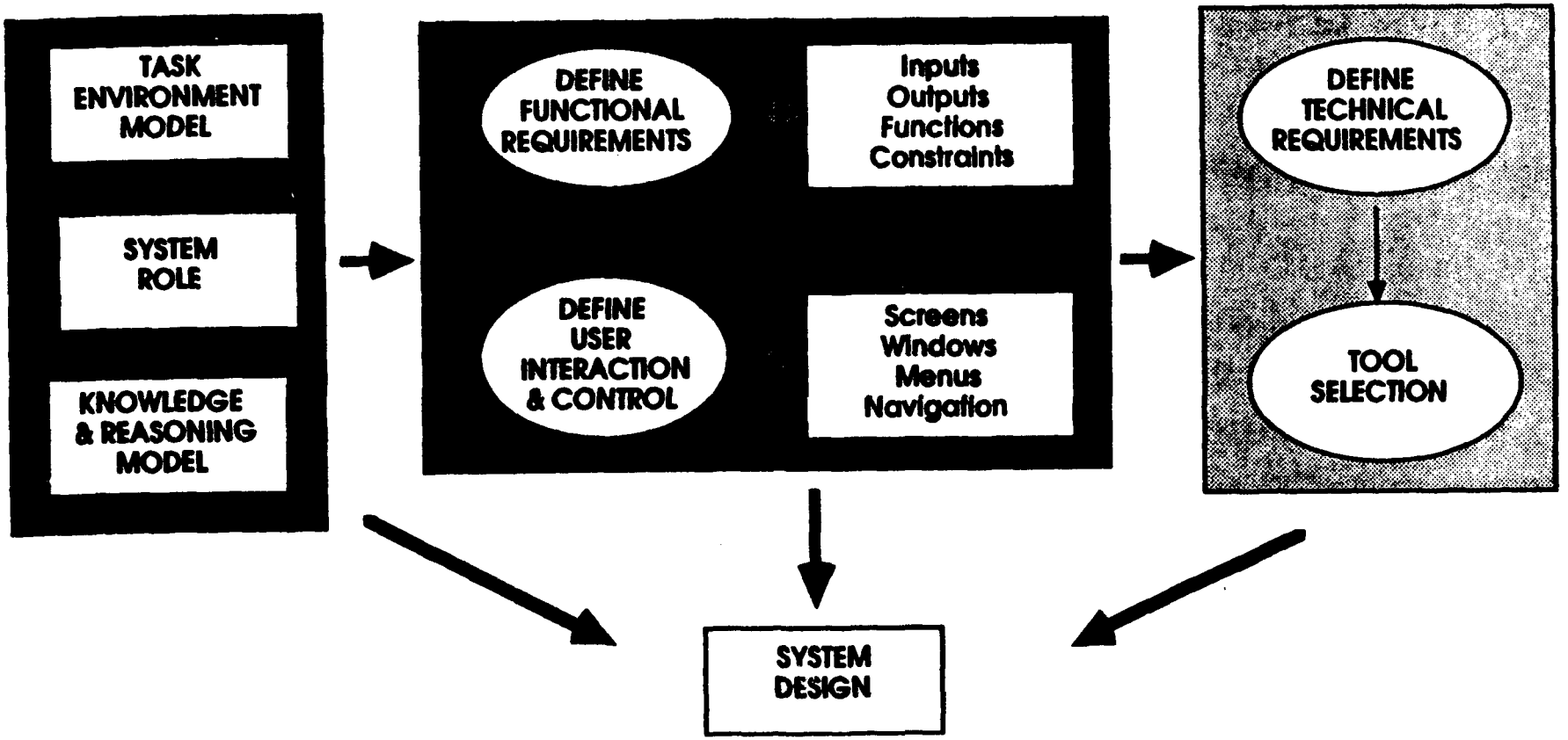
SYSTEM DESIGN



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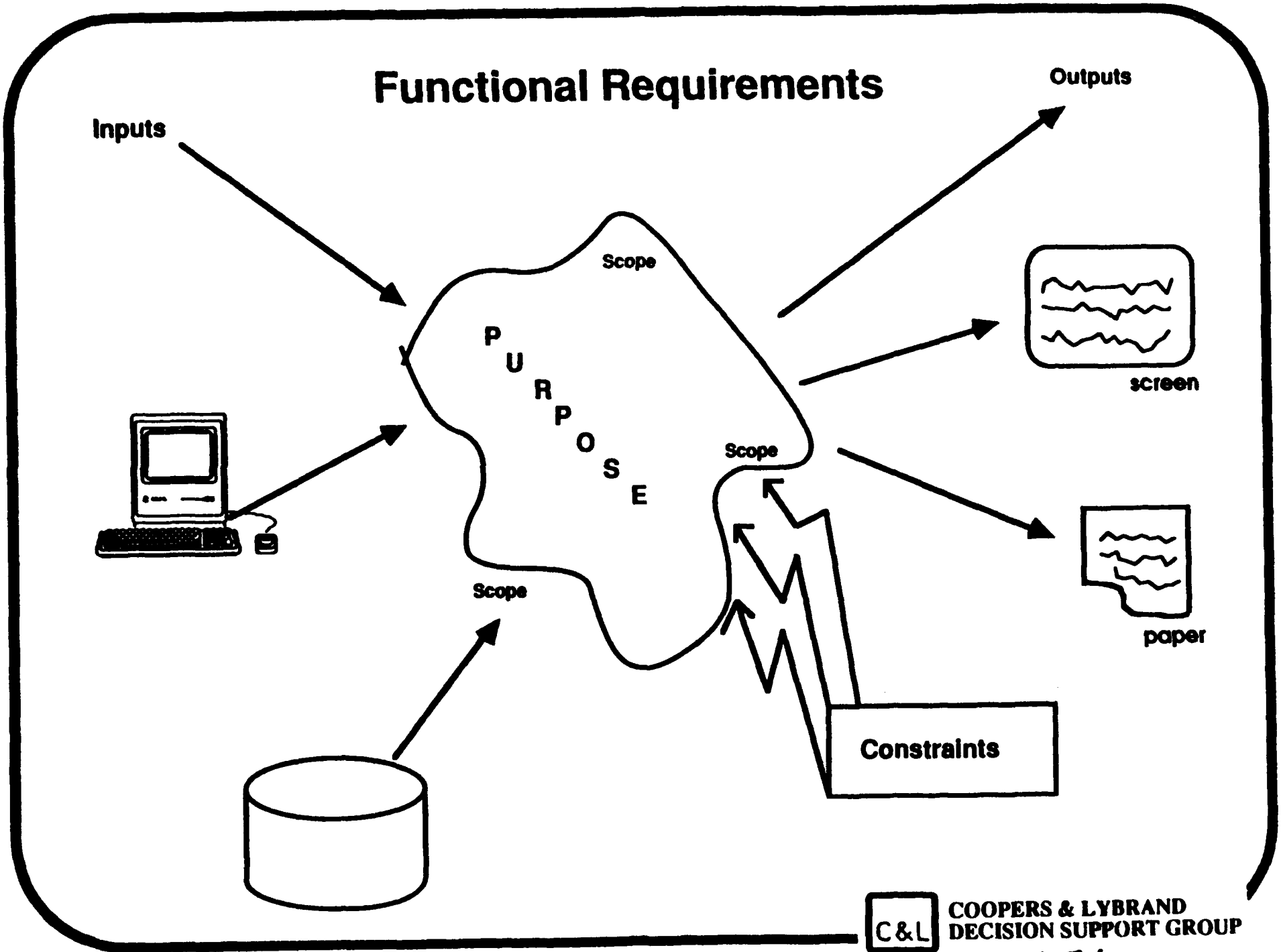
Functional Requirements
Inputs
Outputs
Scope
P U R P O S E
Scope
Scope
screen
paper
Constraints
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FUNCTIONAL REQUIREMENTS

- **Allocate System Roles**
  - **Human vs. System**
- **Describe System Behavior**
- **Establish Human Memory Demands During Task Performance**
  - **What is Remembered**
  - **Who Remembers it**
  - **How is it Remembered**
- **Establish the Location of Representations**
  - **internal vs. external vs. implicit representations**

USER INTERACTION AND CONTROL

- **Define the Script and Mode of User Interaction**
- **Establish What will be Accessible to the User**
  - **use task environment model to insure appropriate cognitive support**
- **Establish Explanation Requirements**
- **Establish Help Requirements**

TECHNICAL REQUIREMENTS

- Define Knowledge Modules
  - what are they
    - objects
    - rules
  - navigation among them
    - forward vs. backward vs. mixed chaining
    - system control
- Define "permanent" system structures
- Define how complexity will be handled
  - flexibility of program
  - multiple knowledge bases
  - specialized versions of the system
- Select Tools

SELECTING TOOLS

TYPES OF TOOLS

CUSTOM SYSTEMS

OFF-THE-SHELF SYSTEMS

OFF-THE-SHELF KNOWLEDGE BASES

APPLICATION SHELLS

DOMAIN TOOLS

GENERIC SHELLS/TOOLS

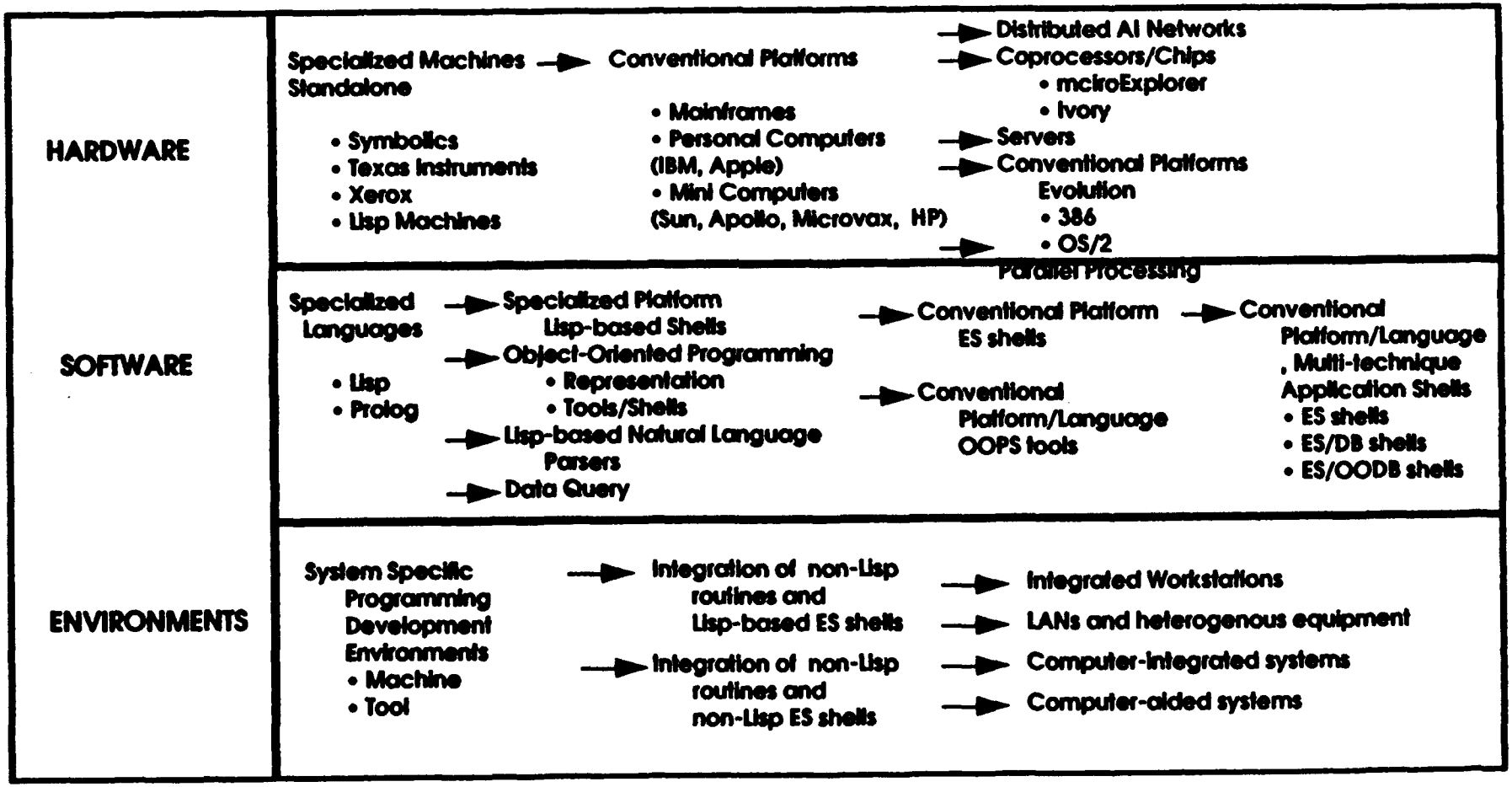
LANGUAGES

ENVIRONMENTS

OPERATING SYSTEMS

HARDWARE PLATFORMS

EVOLUTION OF ES/KBS TOOLS



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EXAMPLES OF AVAILABLE TOOLS

TOOL	DESCRIPTION	EXAMPLES
Custom Systems	knowledge-base systems designed to support a particular function within a specific environment/organization	DEC's XCON, GE's CATS/DELTA, AMEX's Financial Advisor, C&L's ExperTax
Off-the-Shelf Systems	publicly available knowledge-base systems that handle a generic class of problems	SpinPro, MudMan, "Ask Dan" Tax Advisor, DuPont's 313 Advisor, Renault's Transmission Diagnostic Advisor
Off-the-Shelf Knowledge-Bases	publically available "static" knowledge-bases that can be incorporated into a custom system	none currently available -- technology is still too immature
Application Shells	knowledge-based systems that address a specific problem and already have much of the solution built in - require some customization by the user	Palladian's Financial Advisor, Palladian's Operational Advisor, ETI's Directory Expert
Domain Tools	packages that contain the tools to address a specific type of problem but the approach and solution is left to the user	Intellicorp's Simkit, Carnegie Group's Diagnostic Advisor, Gensym's G2, C&L's FFAST
Generic Shells/Tools	packages that contain generic knowledge representation and inferencing tools for developing knowledge-based systems	Inference's ART, Gold Hill's Goldworks, Neuron Data's Nexpert, TI's Personal Consultant Plus, Graphael's GBASE
Languages	computer languages that support a variety of programming features	Lisp, Prolog, C, Pascal, Fortran, Cobol
Environments	integrated programming environments that provide a variety of development tools usually for a specific language	TI Explorer Environment, Gold Hill Common Lisp Envrionment
Operating Systems	machine environments that support file manipulation, memory management, etc	DOS, Windows, UNIX, Finder
Hardware Platforms	physical computer architecture including processor and memory configurations	Compaq 386, Compaq 286 w/Hummingboard, Symbolics machine, microExplorer, Sun, VAX, MAC II, IBM 3070

PERSONAL COMPUTER TOOLS

HARDWARE	SOFTWARE	LANGUAGES/TOOLS
80286	Goldworks	Lisp
80386	Nexpert Object	C
PC XT/AT	Guru	DOS
PS2/60	Aion - PC	Windows
PS2/80	M1	OS-2
RISC	Insight 2+	Finder
MAC II	Personal Consultant +	Networks
Mac SE	Exsys	DBMS
	1st Class	

WORKSTATION TOOLS

HARDWARE	SOFTWARE	LANGUAGES/TOOLS
80386	Goldworks	Lisp
PS/80	Nexpert Object	C
RISC	ART	OPS 5
Mac II	KEE	UNIX
microVax	KnowledgeCraft	Windows
Sun	S1	OS/2
Apollo	G-Base	VMS
Symbolics	Flavors	Finder
TI Explorer		Special
LMI Lambda		Networks
		DBMS

MAINFRAME TOOLS

HARDWARE	SOFTWARE	LANGUAGES/TOOLS
VAX	Nexpert Object	Lisp
IBM	Aion ADS	C
other	ESE	MVS, CICS, etc
	Knowledge Tool	Networks
		DBMS

TOOL SELECTION CRITERIA

- **Complexity requried**
  - **knowledge representation**
  - **reasoning language**
  - **debugging tools**
- **Graphics and Interace Tools**
- **Ease of Use**
- **Hardware Requirements**
- **Portability**
- **Interfaces to Other Systems**
- **Availability**
- **Cost**